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April 1973

EXPERIMENTS AND MODELS IN PRAIRIE SMOKE (U)

Aeronomy Corporation

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EXPERIMENTS AND MODELS IN PRAIRIE SMOKE (U)

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PUBLICATION REVIEW

This technical report has been reviewed and is approved

RADC Project Engineer

ABSTRACT (U)

(S) This report describes satellite transmission experiments carried out in Prairie Smoke III and IV to study the structure sizes and time dependence of scintillations produced by artificial spread F (ASF) irregularities at frequencies of 30, 50, 150, and 400 MHz. Fine structure down to less than 10 m was identified in the scintillating signals. Aircraft and topside sounder diagnostics are described for earlier experiments, which show that the disturbed region extends more than 200 km in a north-south direction, with a relatively sharp southern boundary. This report also presents a criterion for optimization of the bistatic cross section for on-frequency scatter (OFS) at VHF and UHF by a suitable choice of geometry.

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1. INTRODUCTION (U)

(S) During the period September 1, 1972 through February 28, 1973, some additional tests were carried out as part of the Prairie Smoke series; Prairie Smoke III, in September 1972, and Prairie Smoke IV, in November-December 1972. The general purpose of Prairie Smoke III was to test aspects of the scattering model prepared during the previous reporting period; the results are presented in Section 2. Prairie Smoke IV was intended to provide data for a yield model. Unfortunately, weather conditions were extremely adverse, and only limited data were obtained. These data are presented in preliminary form in Section 3. Work has been proceeding during the past year in the use of various types of mobile diagnostic, such as aircraft-borne and satellite-borne ionosondes, for mapping the spatial extent of the disturbed region. These data are presented and interpreted in Section 4 of this report.

(S) Work has continued on theoretical modeling concepts for on-frequency scatter (OFS), and it is demonstrated in Section 5 that a particular symmetrical bistatic geometry maximizes the total scattering cross section.

2. TRANSMISSION EXPERIMENTS IN PRAIRIE SMOKE III (U)

2.1 Introduction (U)

(S) Two major objectives were set for the transmission experiment in Prairie Smoke III. The first was exploration of the morphology of the disturbed region in an east-west direction using one fixed and one mobile receiver on Navy Navigational System orbiting satellites. The results of these experiments are given in Section 2.2. The second was a study of the height distribution of artificial spread F (ASF) by observing the rise and set of orbiting satellites through the disturbed region from a point far to the south of the heater transmitter. Unfortunately, heater transmissions were not available during the second week of Prairie Smoke III when this experiment was scheduled. It had been hoped to carry it out in Prairie Smoke IV, but the extremely adverse weather conditions prevented this also. It is hoped, therefore, to carry it out in Prairie Smoke V in the summer of 1973.

(S) One subsidiary experiment was carried out in Prairie Smoke III; transmission studies of satellite-borne 30- and 50-MHz pulsed beacon transmitters. These results are shown in Section 2.3.

(S) Correlation analysis is being carried out for amplitude records from orbiting satellite signals taken with spaced antennas; as described in Section 2.4, these have shown the presence of much smaller structure sizes (down to about 10 m) than had previously been measured with the transmission experiment.

2.2 Transmission Experiment Studies of East-West Morphology (U)

(S) Since most satellites are polar-orbiting, and therefore cross medium latitudes in a generally north-south direction, transmission experiments from

them can be used to study the north-south morphology of ASF, as described in the Prairie Smoke II Proceedings (pp. 46-77). Studies of the east-west morphology are more difficult, however, requiring use of more than one receiving location. In Prairie Smoke III, the following sites were used:

Walcott, Wyo.	41.69°N, 106.80°W
Pine Bluffs, Wyo.	41.17°N, 104.03°W
Hillsdale, Wyo.	41.15°N, 104.47°W

(S) The trailer-mounted receiving system was located at Pine Bluffs, while the more mobile system was used at Walcott and Hillsdale. Passes recorded during the first week of Prairie Smoke III are shown in Table 2.1. The second column gives the time at which the line of sight (LOS) from the satellite to the ground station crossed the heater transmitter latitude at a height of 250 km. The fourth column gives the heater frequency and, in parentheses, the value of foF2 at the time of transit. The next column gives the satellite transmitter frequency f: h_T is the height of the LOS when passing vertically over the heater transmitter: d_T is the distance east of the heater of the line of sight at 250 km altitude at the time given in column 2. In the last column, a range of values is given for 4-second averages S_R of the rms percentage fluctuation of the amplitude; and S_M is half the maximum peak-to-peak amplitude excursion as a fraction of the mean amplitude.

(S) The first and last passes indicated in Table 2.1 are described in detail in Section 2.3. Of the remaining four passes, one (that on September 6) was taken at Walcott, Wyo., approximately 250 km west of the magnetic meridian through Platteville. It passed through the heated region at an elevation angle of about 47 deg. Only residual fading, S = 4%, was seen (Figure 2.1). However, as indicated in Note 1 for Table 2.1, the transmitter was switched

Table 2.1

Data obtained during Prairie Smoke III (S)

Date	Time MST	Site(s)	Heater Mode(foF2)	f(MHz)	h_T(km)	d_T(km)	Fading Observed
Sep. 6	1451:40	Walcott, Wyo.	6.9 MHz cw (8.0 MHz)	30	265	-12	Deep fading like Sep. 9 not observed
Sep. 6	1621:20 Note 1	Walcott, Wyo.	5.95 MHz cw (7.2 MHz)	150	300	-27	Residual fading only
Sep. 7	1922:40	Pine Bluffs, Wyo.	5.2 MHz cw (5.5 MHz)	150	-	54	S_R = 10 - 32 % $S_M \sim$ 60%
Sep. 8	1235:30 Note 2	Pine Bluffs, Wyo.	7.45 MHz cw (7.8 MHz)	150	-	51	S_R = 10 - 28 % $S_M \sim$ 60 %
		Hillsdale, Wyo.		150	-	23	S_R = 8 - 15 % $S_M \sim$ 30 %
Sep. 8	1624:45 Note 3	Pine Bluffs, Wyo.	6.98 MHz cw (7.4 MHz)	150	-	60	S_R = 5 - 8 % $S_M \sim$ 15 %
		Hillsdale, Wyo.		150	-	35	S_R = 5 - 8 % $S_M \sim$ 15 %
Sep. 9	1458:30 Note 4	Hillsdale, Wyo.	9.4 MHz cw (10.15 MHz)	30 50	250	0	Deep fading at 30 and 50 MHz

Notes for Table 2.1 (U)

(S) Note 1: Heater transmitter interrupted immediately prior to satellite transit: off at 1618:53, on again at 1620:45, low power.

(S) Note 2: O trace partly mutilated by heater, making critical frequency determination difficult.

(S) Note 3: At Pine Bluffs real-time chart records only are available for this pass.

(S) Note 4: Erie sounder station reports "spread not outstanding".

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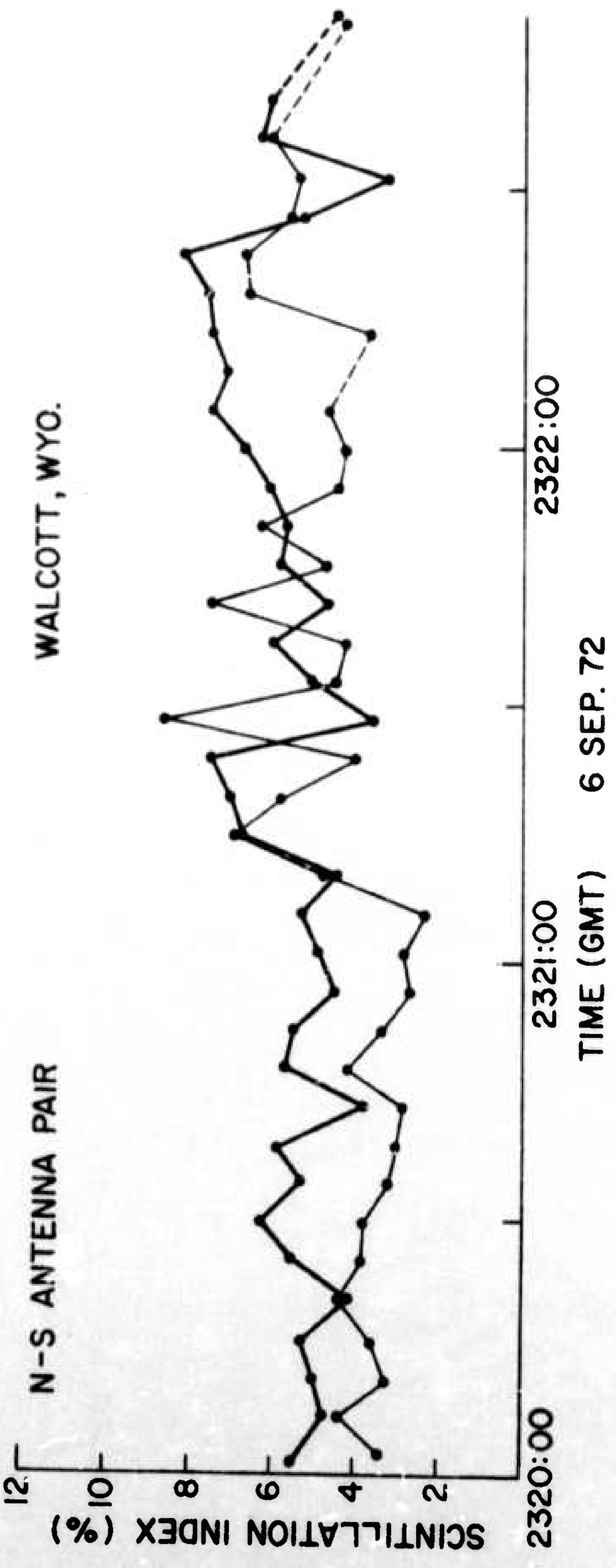

Figure 2.1 Fading of 150-MHz signals on 6 September 1972 (S)

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off immediately prior to the time of transit of the LOS through the heated region. A minimal enhancement (to 5 or 6%) was seen in the scintillation index, about 30 sec after the switch-on time. An additional factor must certainly have been the averaging effect, over many scintillating irregularities, of the large angle the LOS made with the magnetic field.

(S) The next pass was observed at Pine Bluffs on September 7, with an LOS passing about 54 km to the east of the heated region. Here the interesting scintillation pattern shown in Figure 2.2 was observed. The index maximized at about 32% when the line of sight was closest to the magnetic field direction, and the LOS passed closest to the center of the heated region. To compare the observed variation of scintillation index with the cylinder scattering model, a height range plot such as Figure 2 can be used. As described in a previous paper ("Proceedings of Prairie Smoke I RF Measurements Data Workshop", pages 71-73), this diagram imagines a cylinder of radius R with axis the magnetic field direction, whose intersection with the 300-km altitude sphere is centered in the magnetic meridian over Platteville, at a distance X north of that point.

(S) Figure 2.3 shows the height at which the LOS intersects the cylinder as a function of time during the satellite pass. Since Pine Bluffs is located inside the cylinder, the single curve shown for each model represents the height at which the LOS exits the cylinder. Results from Prairie Smoke II suggested that only heights above 200 km along the LOS would contain irregularities able to cause appreciable scintillation of transmitted satellite signals. Therefore, the scintillation region at any given time is approximately bounded by a lower altitude of 200 km and an upper altitude given by the curves of Figure 2.3. Comparison of these curves with the scintillation curve of Figure 2.2 suggests a cylindrical model centered over Platteville,

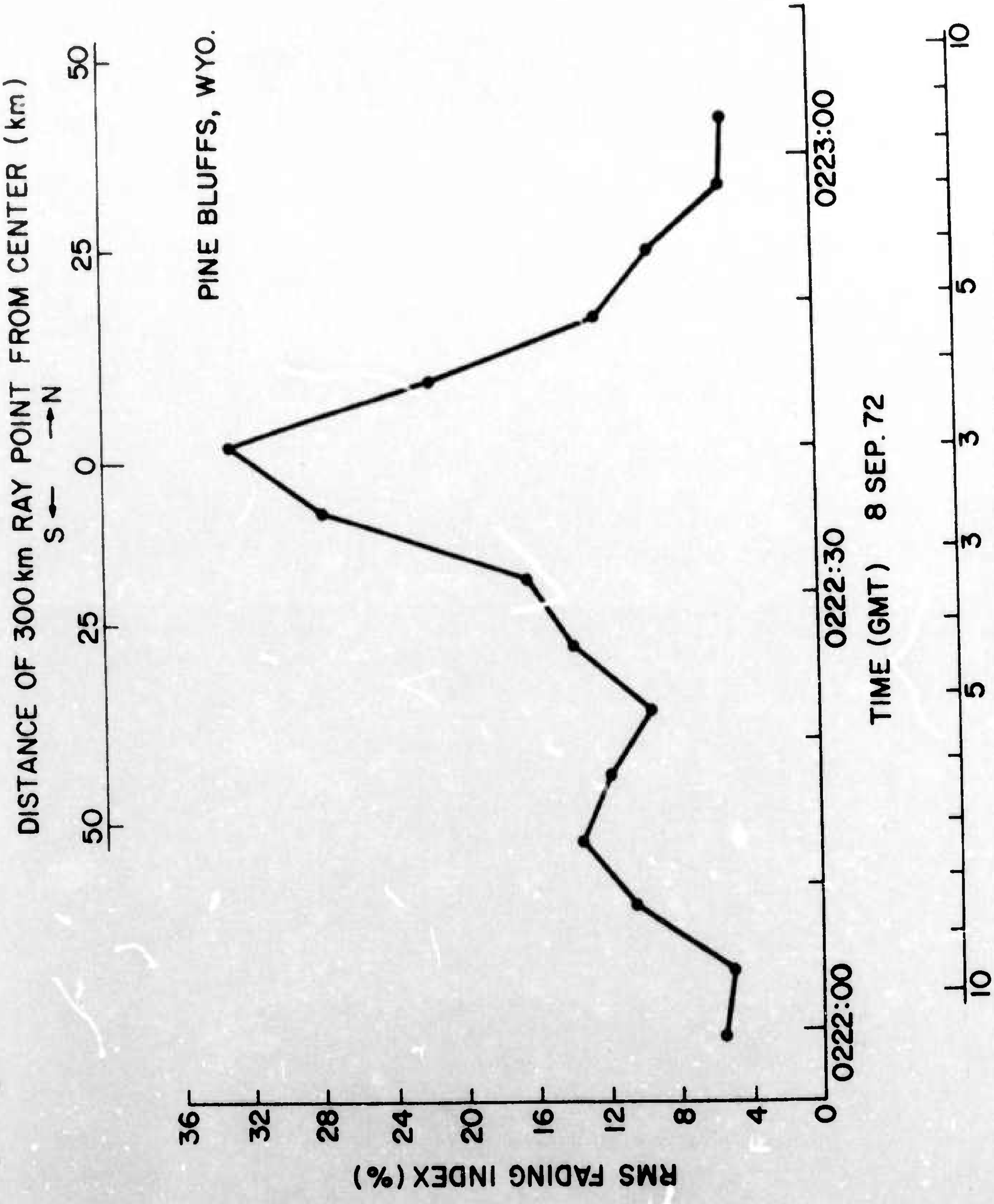


Figure 2.2 Scintillation index for 0222 GMT 8 September 1972 (S)

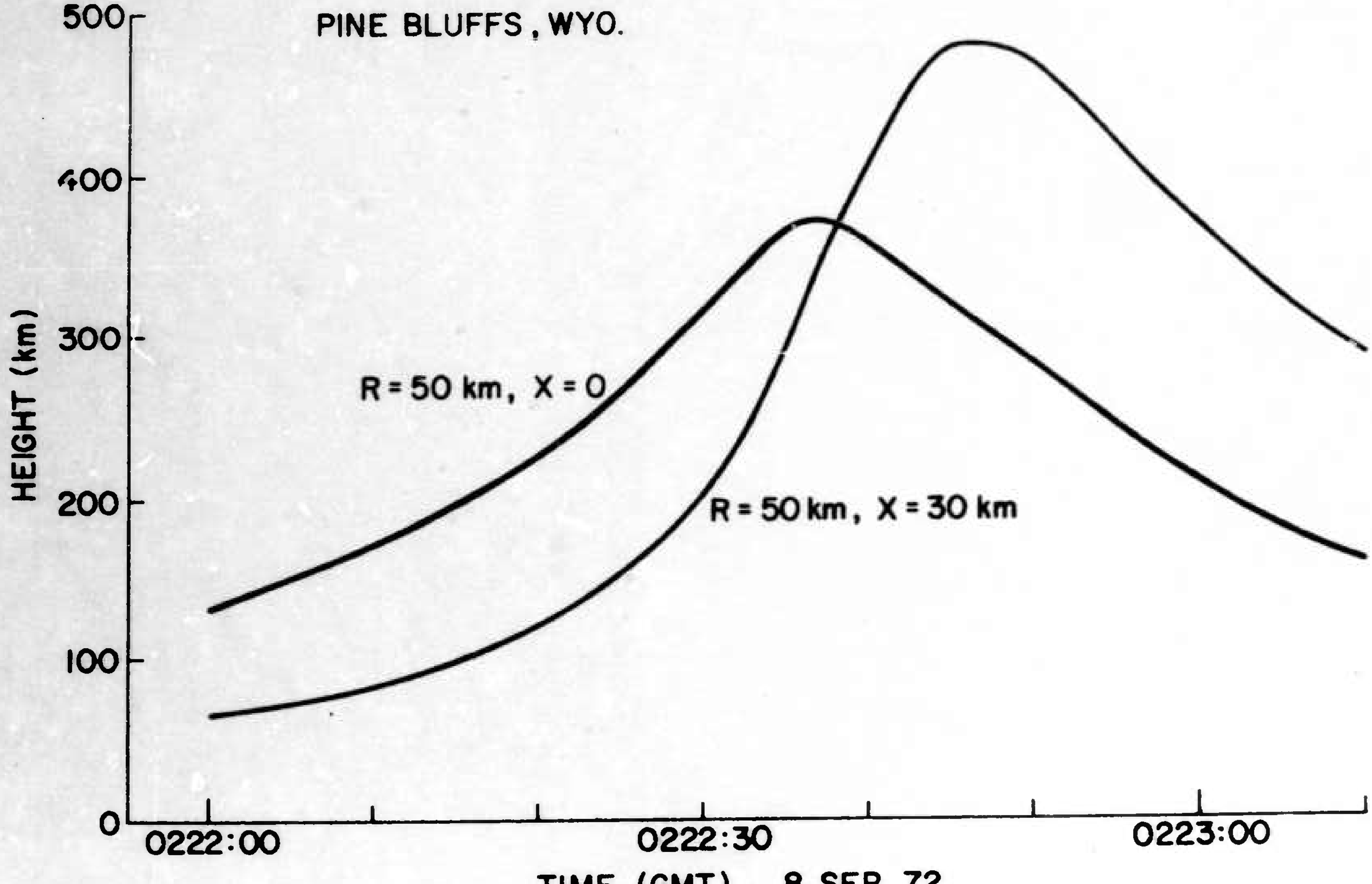


Figure 2.3 Upper limit of scintillation altitude for 0222 GMT 8 September 1972 (S)

with R = 50 km, X = 0.

(S) A second feature of the curve of Figure 2.2, however, is the secondary maximum in the fading index when the ray path passed about 50 km south (and 50 km east) of the center of the heated region. Evidently, this could not be due to favorable magnetic aspect (i.e. LOS nearly along the field lines).

(S) The next pass, around noon on September 8, offered an opportunity to study this effect simultaneously at two sites. Figure 2.4 illustrates the fading index observed at Hillsdale and Pine Bluffs with two distinct maxima approximately centered about the heater location. The northerly maximum, the larger of the two, approximately matches the height extent plot on Figure 2.5 for R = 50 km, X = 30 km; just as in Figure 2.2, a second maximum was seen 50 km to the south of the first. At Hillsdale, however, the fading showed a maximum only about 10 km south of the heater. Therefore, it seems reasonable to suppose that the ASF formed a doughnut-shaped region, with its center about the same latitude as the heater but displaced to the east about 50 km. This suggests the need for great caution in assuming that the shape of the disturbed region corresponds to the polar diagram of the heater transmitter. Interestingly (see Note 2 of Table 2.1), the ordinary-wave reflection was highly distorted at the time of the satellite pass, suggesting that heater-induced horizontal gradients of ionization produce a highly distorted disturbing field of the kind observed in the ASF scintillation.

(S) Exactly opposite behavior was seen in a later pass on September 8, also observed at Pine Bluffs and Hillsdale (Figures 2.6 and 2.7). Here the scintillation reached a maximum for both sites at a time corresponding approximately to the disturbed region being centered over the heater, but with a much larger diameter cylinder, corresponding perhaps to R = 100 km rather than 50 km.

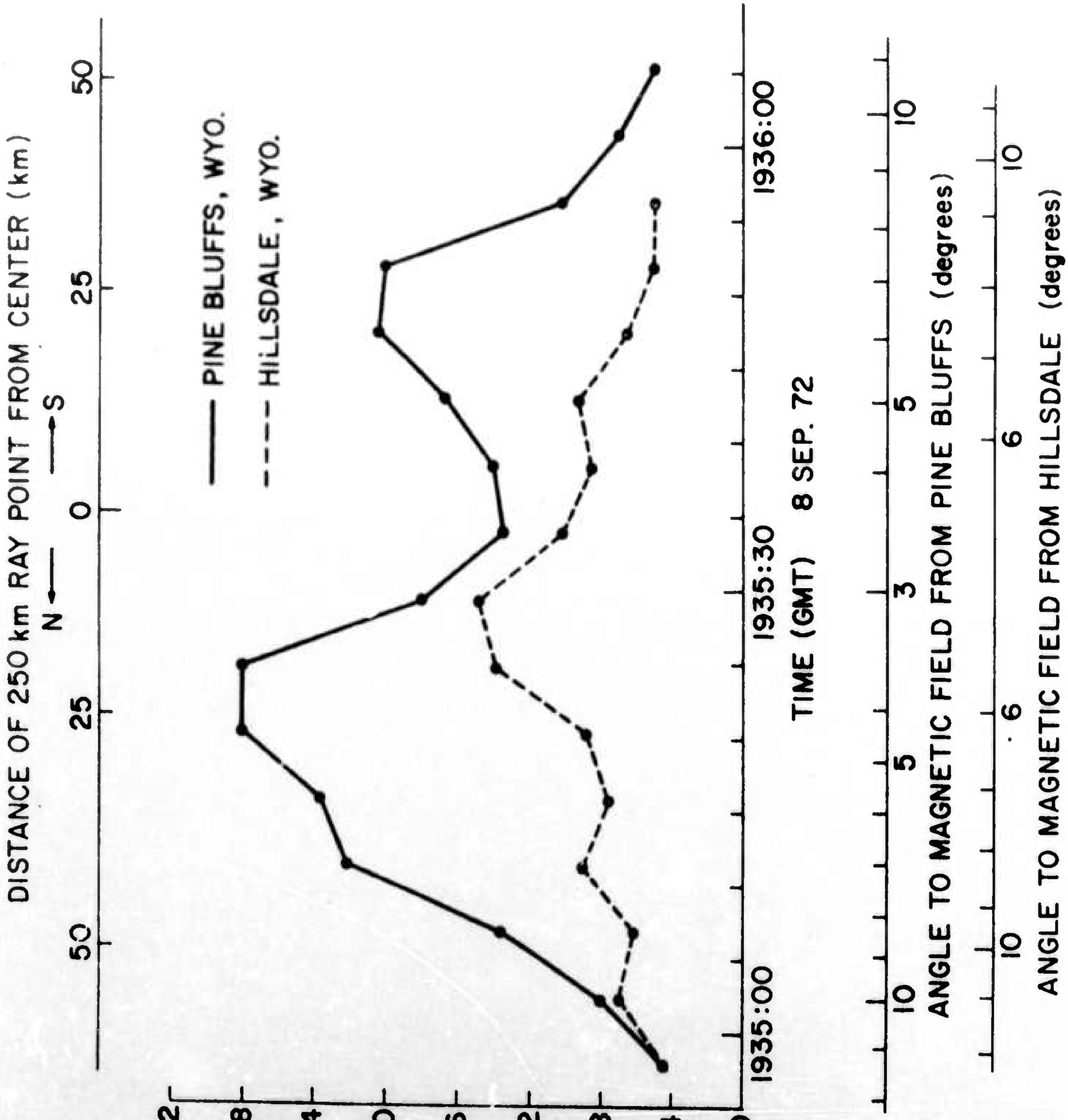


Figure 2.4 Scintillation index for 1935 GMT 8 September 1972 (S)

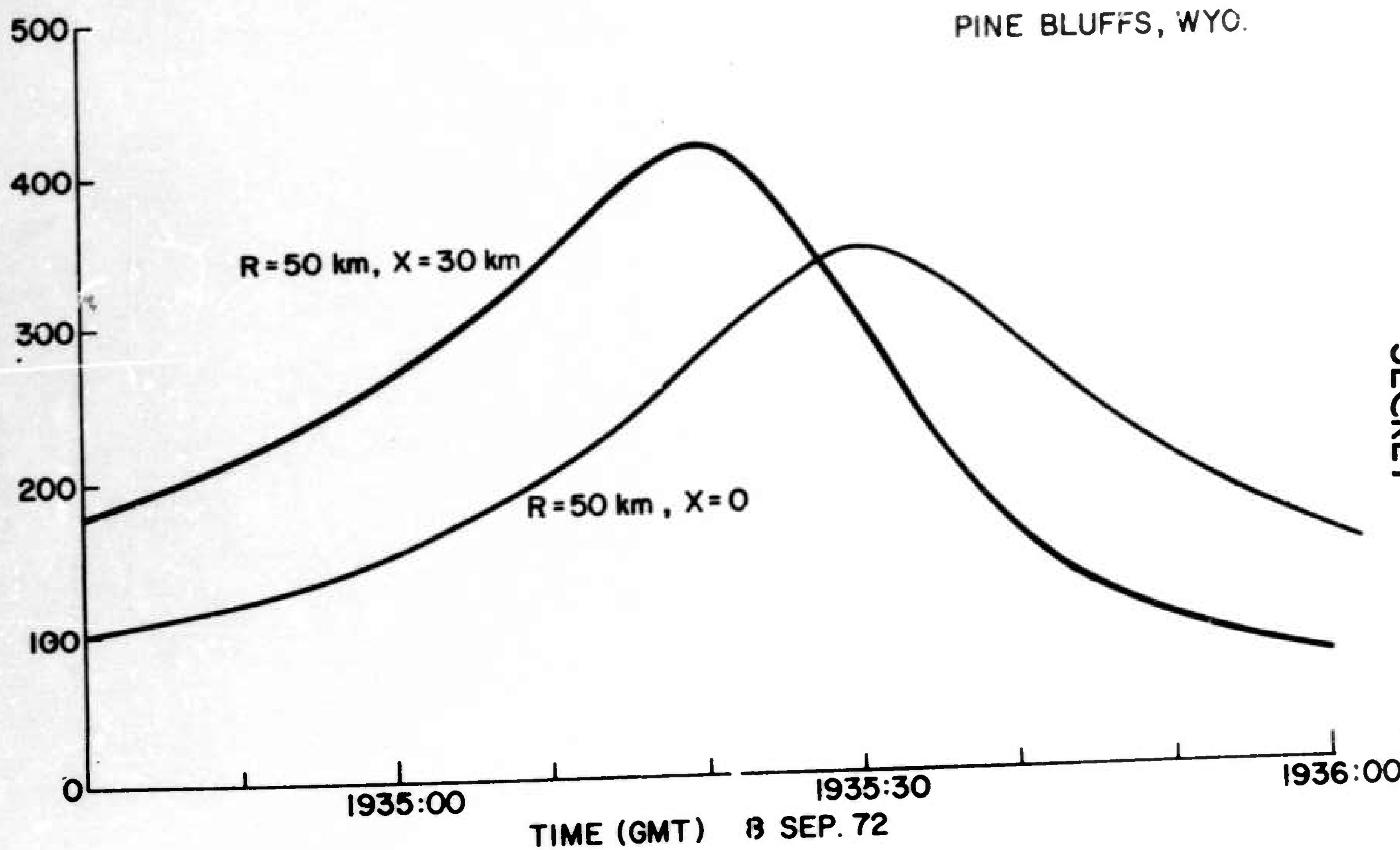


Figure 2.5 Upper limit of scintillation altitude for 1935 GMT 8 September 1972 (S)

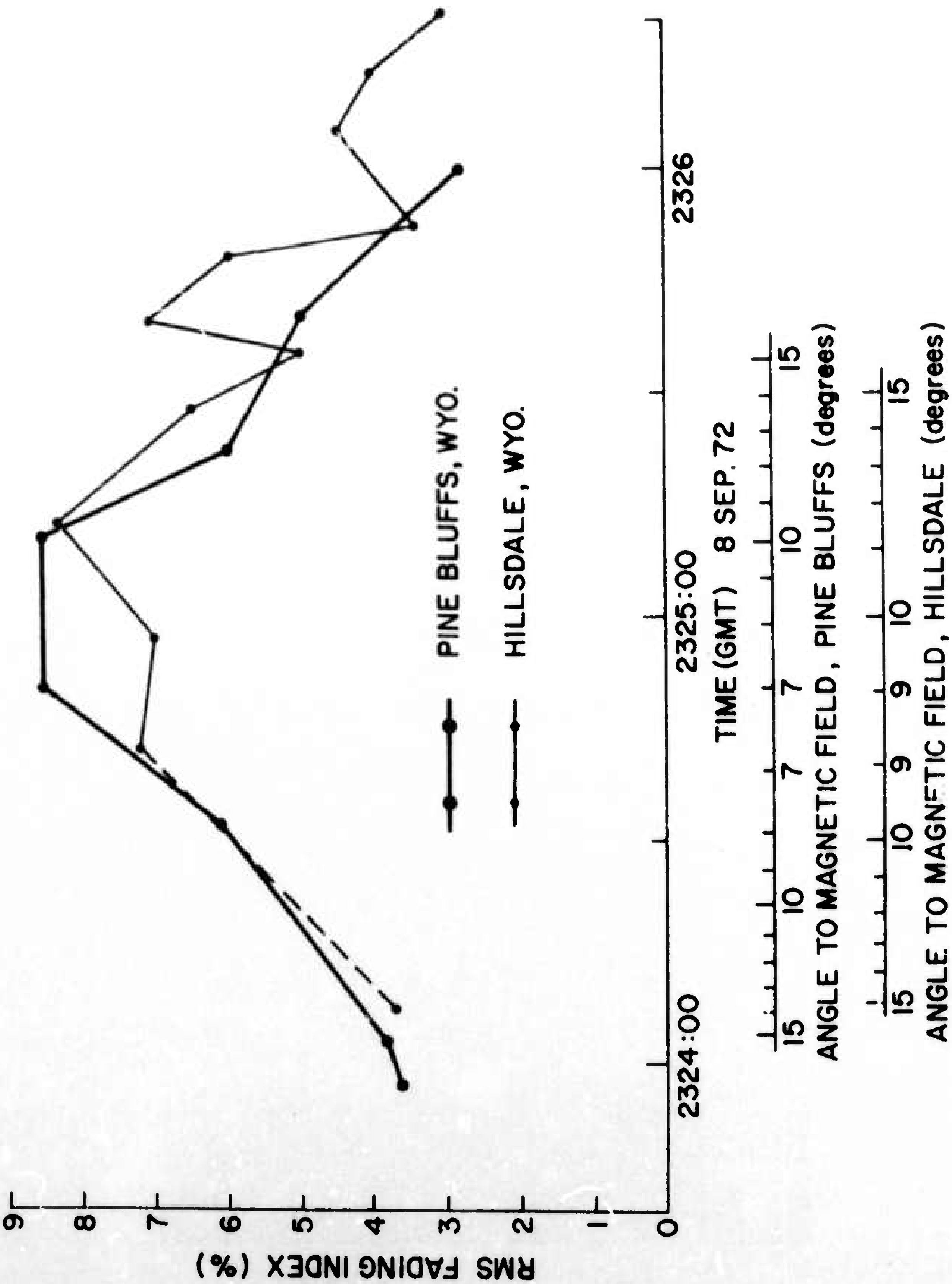


Figure 2.6 Scintillation index for 2324 GMT 8 September 1972 (S)

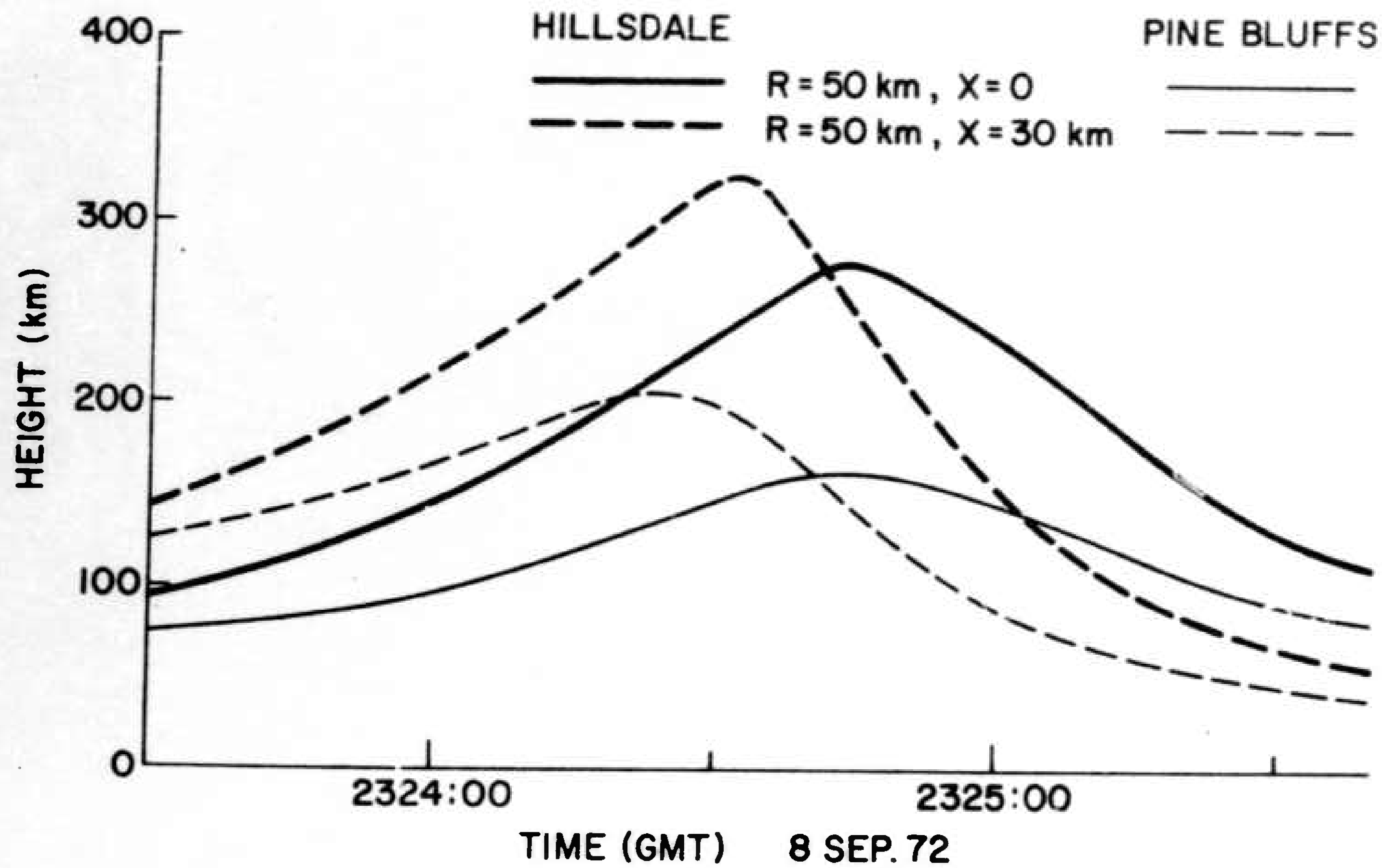


Figure 2.7 Upper limit of scintillation altitude for 2324 GMT 8 September 1972 (S)

It is important to note that the relative distances east of the heater transmitter for the two sites for this pass (60 and 35 km) are not too different from those for the previous pass illustrated in Figure 2.4 (51 and 23 km), so there is no alternative to supposing a real change in the morphology of the disturbed region.

2.3. Transmission Experiment on Pulsed Transmitters (U)

(S) The Lockheed aircraft satellite STP-71-2 carries on it a pulsed beacon transmitter, part of the "ERIS" experiment. This transmitter radiates on frequencies of about 20, 30 and 50 MHz, the 30-MHz transmission being from a linearly polarized antenna, the other frequencies from a circularly polarized antenna. Each pulse is 2 msec duration and 100 w peak power, eight pulses per sec. These pulses are received again at the satellite after reflection from the ground, having passed through the ionosphere twice. The satellite receiver samples the reflected pulse and stores the sample amplitudes in an on-board tape recorder.

(S) As indicated in Table 2.1, two passes of this satellite were observed. The first, on September 6 at 1451 MST was observed from Walcott, Wyo., about 250 km west of the magnetic meridian through the heating transmitter. Though the LOS passed nearly through the center of the heated region, the scintillations observed were minimal, probably due to the unfavorable geometry. Figure 2.8 shows the time variation of the received transmitter pulses during the critical time.

(S) On September 9, however, at 1458 MST, the same satellite was observed from Hillsdale in a direction much more nearly up the magnetic field line, and deep fading was observed at both 30 and 50 MHz. Figure 2.9 shows the amplitude of the beacon pulse signals at 30 MHz. Up to 2158, regular fading

Figure 2.8 Pulsed beacon satellite amplitude at 30 MHz.(S)

Figure 2.9 Pulsed beacon satellite amplitude at 30 MHz.(S)

with about 2.5 sec is observed, produced by Faraday rotation of the transmitted linearly polarization (a simple folded dipole antenna was used). At 2158:07, the uniformity of the fading begins to disappear; by 2158:15 the transmitted signal is essentially completely random. Slower fading reappears at 2158:45, and uniform Faraday rotation resumes at 2159:10. Close study of the region of rapid scintillation on an expanded scale reveals that the amplitudes of successive pulses are essentially uncorrelated, indicating the presence of fading with frequency greater than 8 Hz.

(S) The disappearance of the regular Faraday fading indicates the presence of phase scintillations greater than 1 radian, and this experiment therefore provides a sensitive indication of the presence of ASF and of its geographic extent. One radian of phase fluctuation at this frequency would correspond to about 0.2 radians at 150 MHz, and therefore about 14% amplitude fluctuation for fully developed scintillations, in general accord with the results of Section 2 and of previous Prairie Smoke tests.

2.4 Fine Structure (U)

(S) Careful examination of scintillations at 150 MHz from orbiting satellites whose LOS passes through the disturbed region shows a predominant fading period of about .2 to .5 sec, produced by the interaction of the satellite motion and a relatively fixed pattern of ionospheric irregularities. The autocorrelation function of the amplitude fading can be determined by playing back analog tape recordings of the scintillating signal and digitizing using a PDP-8E minicomputer. When a detector time constant of 2 msec is used, the autocorrelation function is typically found to be displayed in Figure 2.10, as the sum of two approximately Gaussian functions. The wider of these corresponds to the predominant fading referred to above. The narrower component

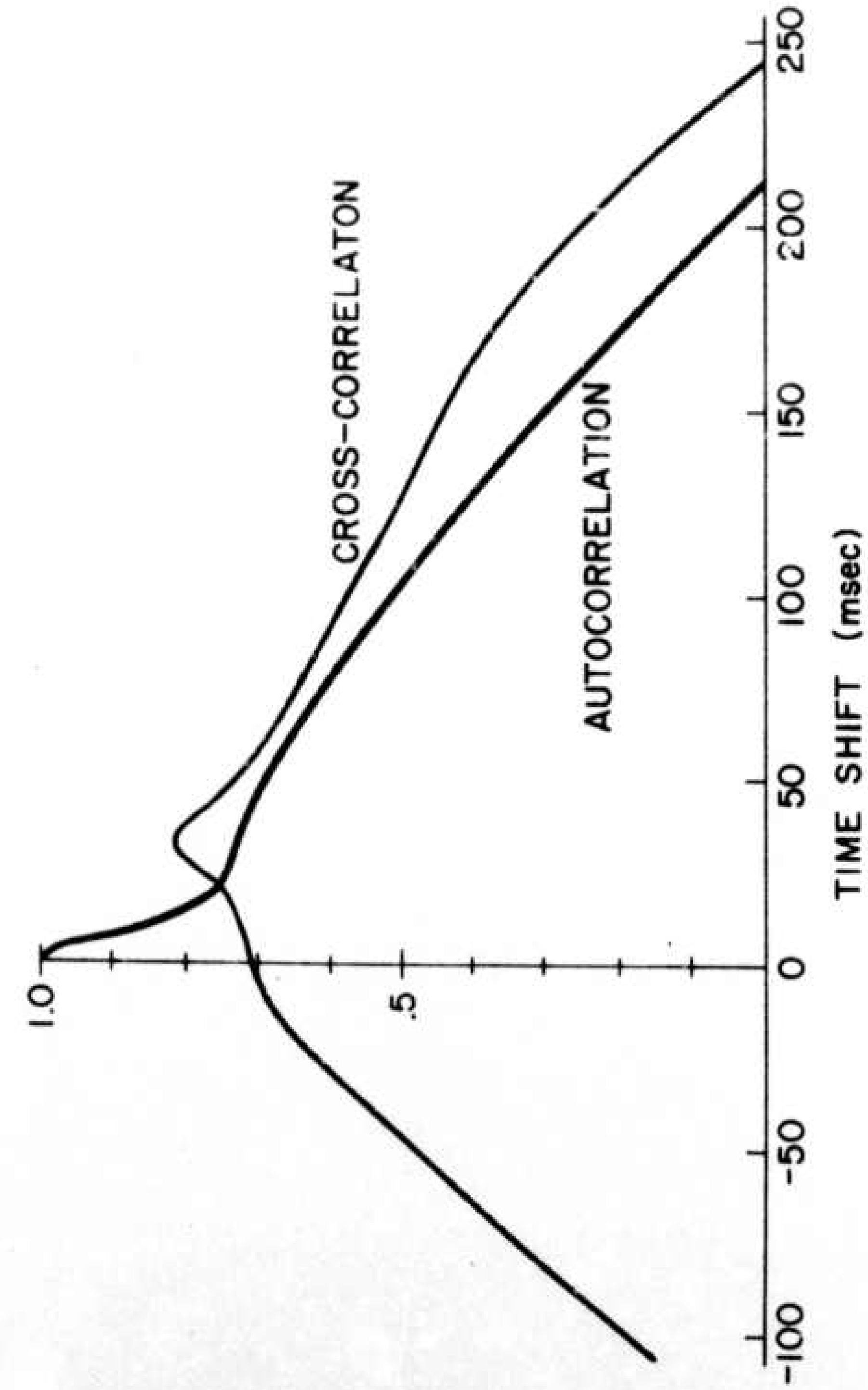


Figure 2.10 Auto- and cross-correlations showing fine structure (S)

one might attribute to noise or to some amplitude modulation on the satellite signal. However, its cross-correlation function between two spaced antennas shows (Figure 2.10) a similar double Gaussian function, but with a maximum displaced about 32 msec. This can only mean that the rapid fading arises because of small structure in the ionosphere, of the order of 10 m or less in the width of its spatial autocorrelation function. The study of this fine structure will be pursued to see if it can be directly correlated with irregularities associated with HF and VHF field-aligned backscatter.

3. PRELIMINARY DATA FROM PRAIRIE SMOKE IV (U)

3.1 Introduction (U)

(S) Since the major emphasis in Prairie Smoke IV was to be the gathering of data for a yield model, emphasis was placed on obtaining scintillation data from geostationary satellites. In this way time variations of the scintillation index could be followed continuously. The experimental plan included the simultaneous use of two geostationary field sites; one located so that the line of sight passed directly through the center of the distrubed region, the other mobile station moving to locations to the west and south of the fixed station to map yield properties of other parts of the disturbed volume.

(S) Unfortunately, extremely heavy snow throughout the experimental period prevented use of the mobile field station and somewhat impaired the operation of the field equipment. In addition, the heating transmitter itself suffered serious difficulties from the weather. Therefore, no orbital data were obtained, and only limited geostationary data. These are described in the following section.

3.2 Preliminary Geostationary Data (U)

(S) The optimum location for geostationary observations using the ATS 5 satellite is in the neighborhood of Lance Creek, Wyoming. However, the distance of that point and the extreme difficulty of access during the heavy snow conditions during Prairie Smoke IV dictated a location somewhat further south. The fixed and mobile field stations were in place from Novenber 28 to December 9, 1972. Good geostationary scintillation observations using real-time chart recordings, analog magnetic tape and digital tape data were obtained. Preliminary scintillation-index data are shown in Figures 3.1 and 3.2.

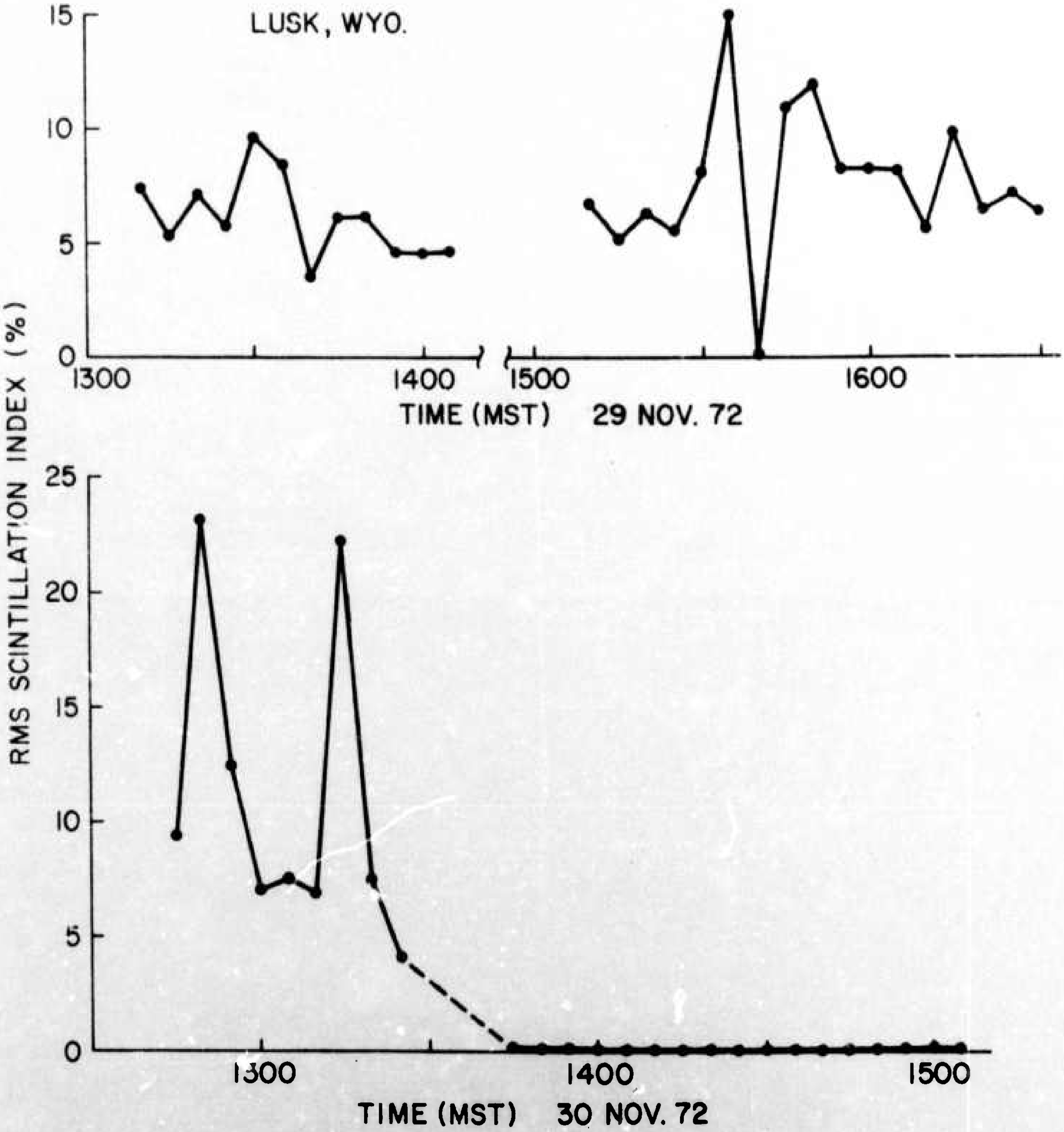


Figure 3.1 Scintillation index for Prairie Smoke IV (U)

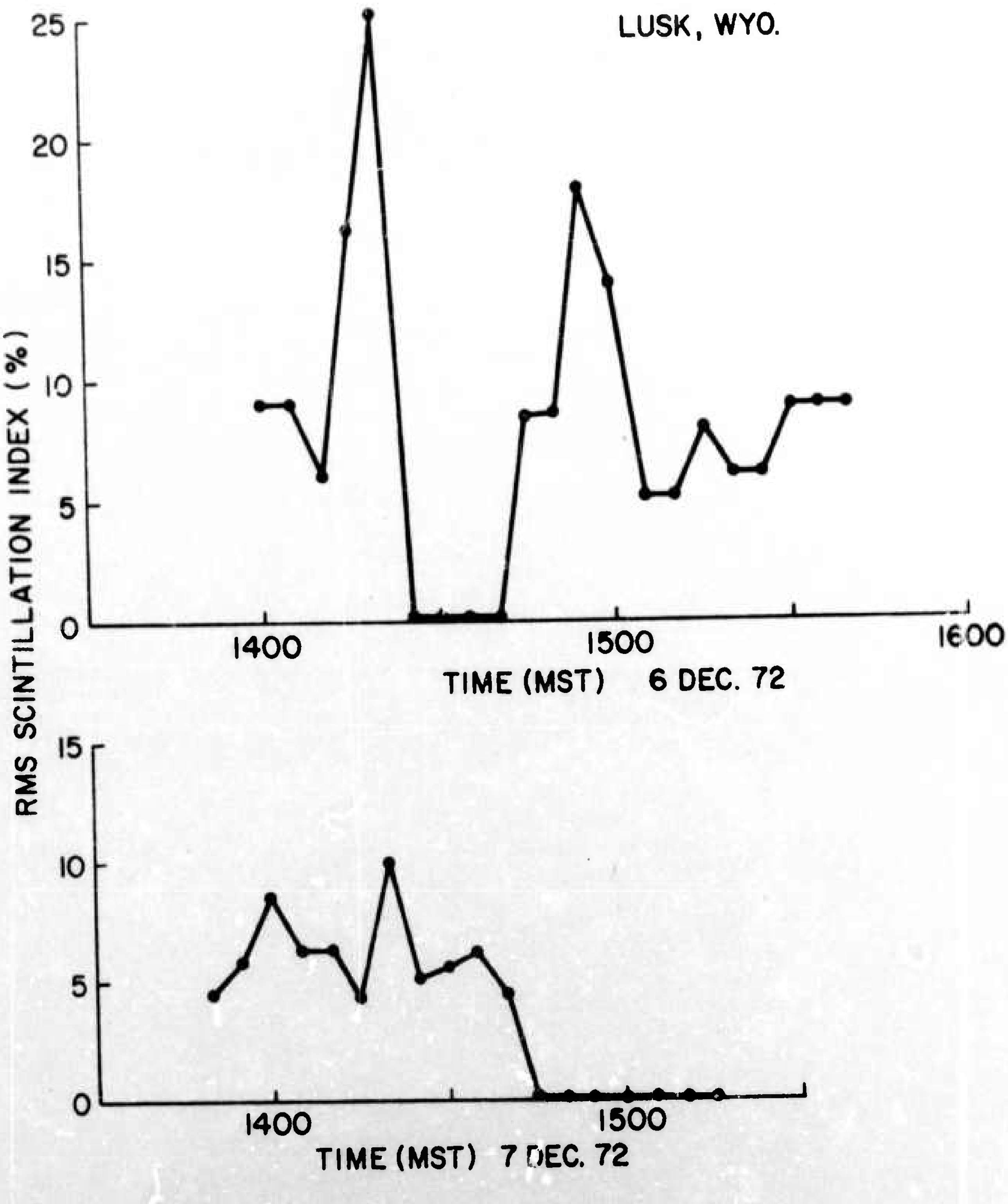


Figure 3.2 Scintillation index for Prairie Smoke IV (U)

(S) After some initial difficulty with the hardware interface, the software for processing the digital data on the PDP-8E computer has been completed, and the final data for Prairie Smoke IV will use the much more accurate results computed from those data.

4. MOBILE DIAGNOSTICS FOR PRAIRIE SMOKE (U)

4.1 Introduction (U)

(S) The measurement of the horizontal extent of the disturbed region over an ionospheric heater is of great importance in establishing models suitable for system studies. Four types of experiments have been available to give this information:

1. Monostatic radar scatter from stations south of Platteville (e.g., White Sands or Albuquerque, New Mexico)

(S) The range depth of the irregularities is partly limited by the latitudinal extent of the heated region; however, the orthogonality (or height-matching condition tends to be even more limiting unless a large number of receiving sites are used.

2. Optical diagnostics of red-line emission

(S) In nighttime experiments with O-wave heating, the horizontal distribution of the 6300Å line can be measured and correlated with RF observations. However, sufficient observations of this kind are not yet available to set the relationship with confidence.

3. Orbital satellite transmission data

(S) This technique has two limitations: first, it measures irregularities averaged along the line of sight, and second, its sensitivity diminishes as the angle between the line of sight and the magnetic field increases. However, it can give useful data if information is available about the altitude distribution of the irregularities.

4. Circular phased array

(S) This measures the cone angle of HF reflections from the ionosphere, but the geometry of the reflections becomes less favorable with increase of angle to the vertical; therefore, irregularities far from overhead the heater appear differently than those immediately overhead.

(S) One of the most sensitive diagnostics for operation at a fixed location is the vertical-incidence ionosonde. It therefore seems appropriate to investigate whether a mobile ionosonde may give useful information about the horizontal extent of the disturbed region. Two approaches to this problem have been used successfully: the first using an airborne ionosonde flying in a north-south path, the second using a polar-orbiting topside sounder satellite. These two experiments are described in Sections 4.2 and 4.3.

4.2 Airborne Experiment (U)

(S) The purpose of this experiment was to determine the feasibility of using an aircraft-borne ionosonde to determine the horizontal extent of the F2 layer over which spread-F effects were visible.

(S) Through contact with Dr. G. J. Gassmann of the Ionospheric Physics Laboratory of AFCRL, the AFCRL aircraft was flown over the Platteville area on March 29 and 31, 1971. The aircraft was supervised by Dr. Gassmann; and the ground-based operations were in the charge of Mr. E. J. Violette of the Office of Telecommunications.

(S) At an initial planning meeting with Dr. Gassmann and Dr. W. F. Utlaut, a magnetic north-south path was laid out over two VOR beacons passing about 5 km east of Platteville. Five reference points were selected along this line, numbered consecutively passing from south to north as follows:

1	Southmost point	
		60 km
2	Denver VOR	
		35 km
	Platteville	
		38 km
3	Gill VOR	
		60 km
4	---	
		60 km
5	Northmost point	

Distances are indicated between the successive points.

(S) The experiment matrix is shown in on Figure 4.1. In each case, the aircraft flew in a magnetic north-south direction for about a three-hour period in the morning. The appropriate times at which it passed each of the points 1 through 5 are indicated on Figure 4.1. The heating transmitter was at 8.8 MHz on March 29, radiating extraordinary mode. On March 31, the transmitter radiated ordinary mode on 6.82 MHz. In each case, the aircraft scans continued both before the onset of heating and following its termination.

(S) Airborne ionosondes are, of course, more susceptible to broadcast interference than ground installations, because of their less directed antenna and the smaller attenuation of the direct signal from the stations. However, spread can be clearly seen. Figure 4.2 is a ground ionogram showing substantial artificial spread F (ASF) and Figure 4.3 is the corresponding aircraft ionogram. All the effects visible on the ground-based ionosonde can also be seen on the aircraft ionosonde. For comparison, Figures 4.4 and 4.5 show corresponding ground-based and aircraft-borne ionograms before the heating commenced. The most prominent feature with O-wave heating is range spreading on both the O and X traces. However, the characteristic absorption of the O-wave is also visible between the heating frequency and the (higher) foF2. To provide some numerical

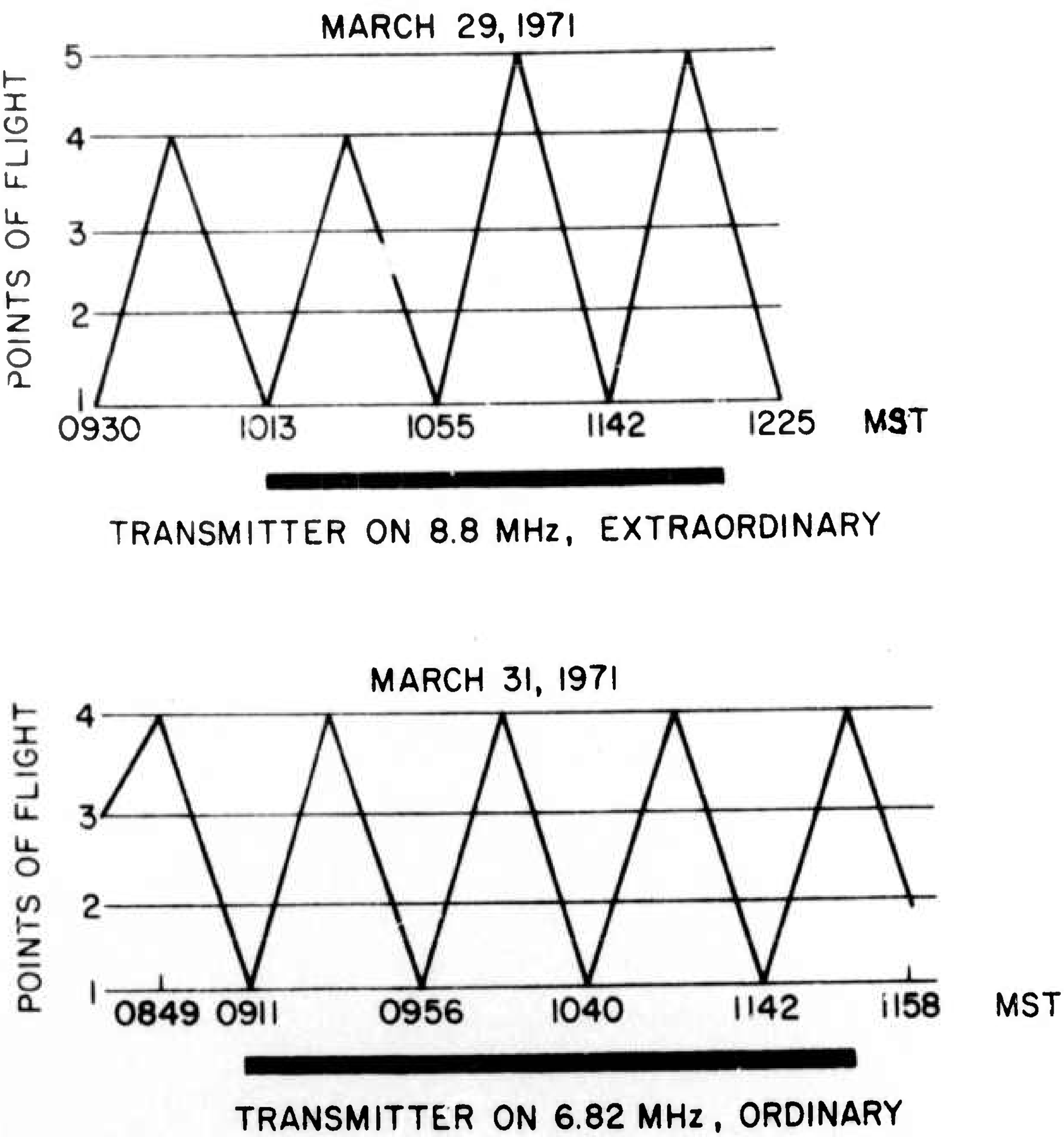


Figure 4.1 Aircraft ionosonde experiment matrix (S).

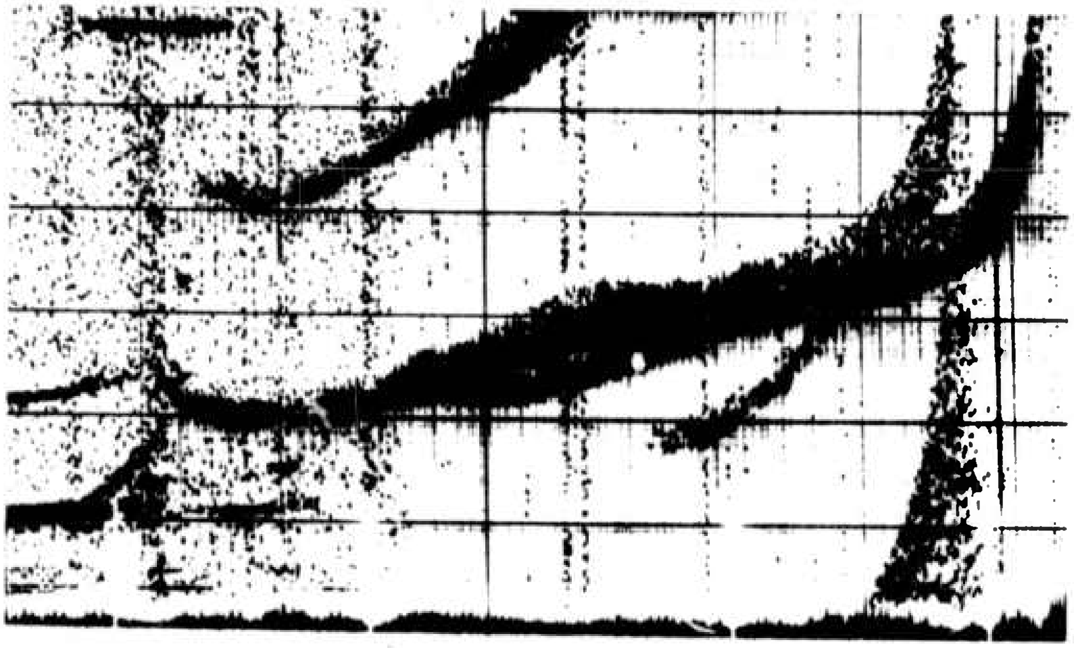


Figure 4.2 Ground ionogram, 0922 MST March 31, 1971 (U)

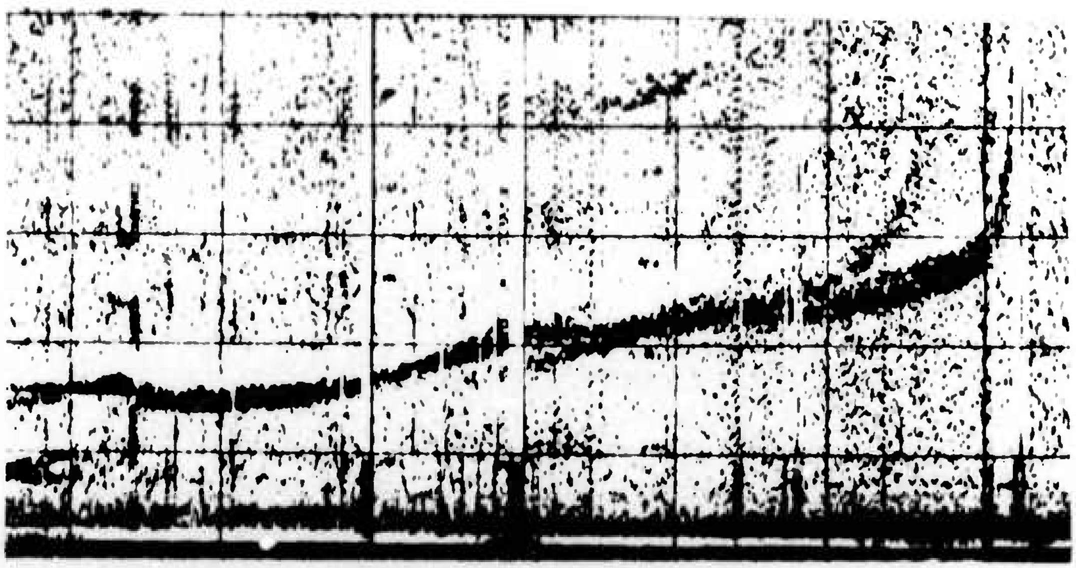


Figure 4.3 Aircraft ionogram, 0922 MST March 31, 1971 (S)

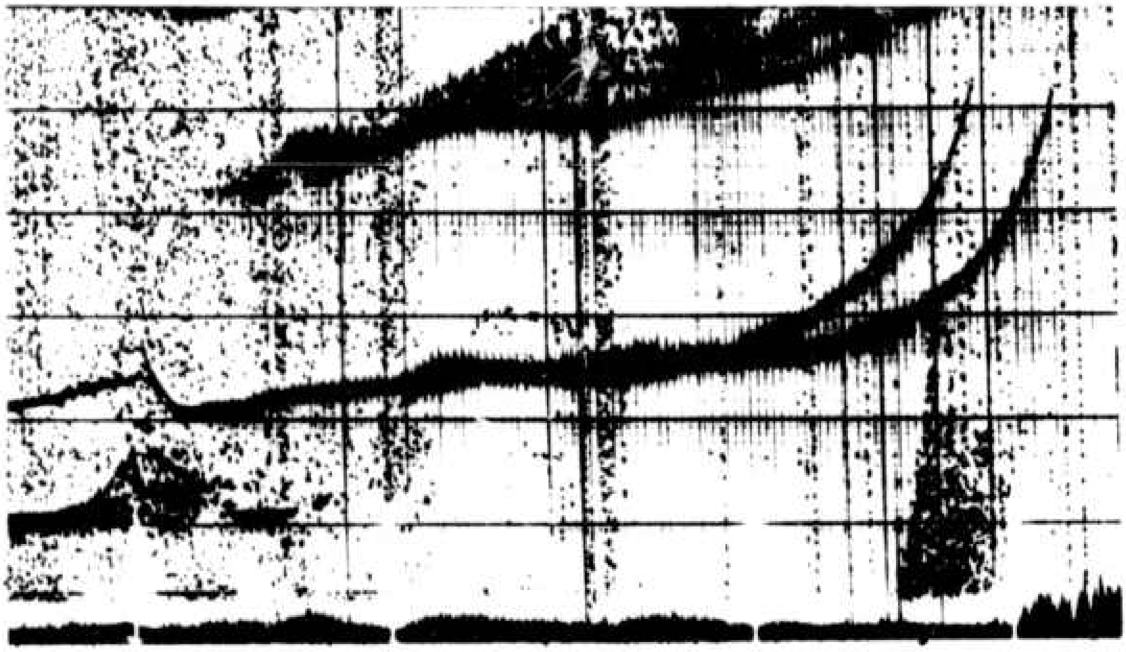


Figure 4.4 Ground ionogram, 0906 MST March 31, 1971 (U)

Figure 4.5 Aircraft ionogram, 0906 MST March 31, 1971 (S)

index of this spread, the width of the extraordinary trace was measured at a frequency immediately above its separation from the O-wave trace. A plot of this quantity versus time for the first northward and southward flight with the heater on are shown on Figure 4.6. The trace width for the ground ionosonde increases rapidly following heater switchon, and remains high throughout the remaining time (though with some decrease at about 0925 MST). On both the northward and southward pass, the airborne ionosonde trace shows a maximum width directly over the heater, decreasing to about half its value about 100 km north. However, on both traces a rather sharp southern boundary is seen with the width decreasing by a factor of two between about 50 and 80 km south of Platteville, reaching its undisturbed value about 90 km south. At 100 km north, the width is still about 50 percent above its undisturbed value.

(S) On the other day (March 29), X-wave heating was used with the heater frequency above fxF2 in the early part of the flight, but below fxF2 after 1056 MST. Using a numerical index for values from 0 to 2.5 depending on the appearance of extra traces and spread on the ionogram (Table 4.1), graphs for this index are obtained as shown in Figure 4.7. In the first three of the north-south passes, essentially zero disturbance is seen in a region more or less centered over the heating transmitter, exactly as one expects given a toroidal or "doughnut-shaped" disturbed region. Such a region is expected if a disturbance is produced only where the heater wave is reflected; namely, somewhat obliquely if the heater frequency is above fxF2. On the fourth scan, a disturbed X trace is seen as much as 120 km north of the heater transmitter.

(S) It is concluded that an aircraft-borne ionosonde is capable of mapping the horizontal extent of ASF under a heated ionosphere, though the quality of the ionograms is not as good as from a ground ionosonde.

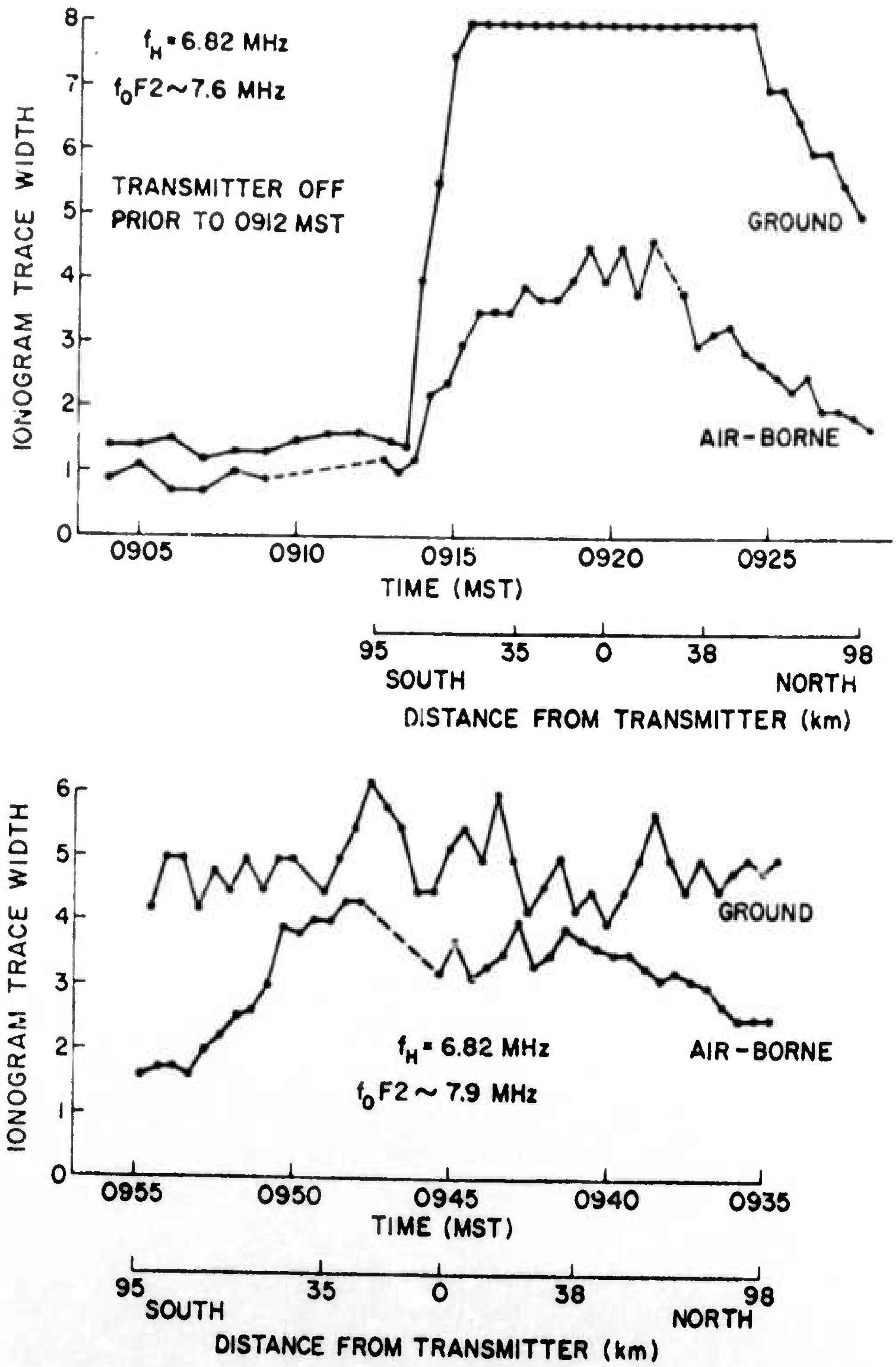


Figure 4.6 Ionogram trace width on March 31, 1971, O-mode heating (S)

Table 4.1

Numerical disturbance indices for X-mode (U)

0.5	Dual O + X F-traces
1.0	Spread O F-trace
1.25	Spread O F-trace plus dual traces
1.5	Spread X F-trace plus dual trace
2.0	Spread O + X F-traces
2.5	Spread O + X F-traces plus dual traces

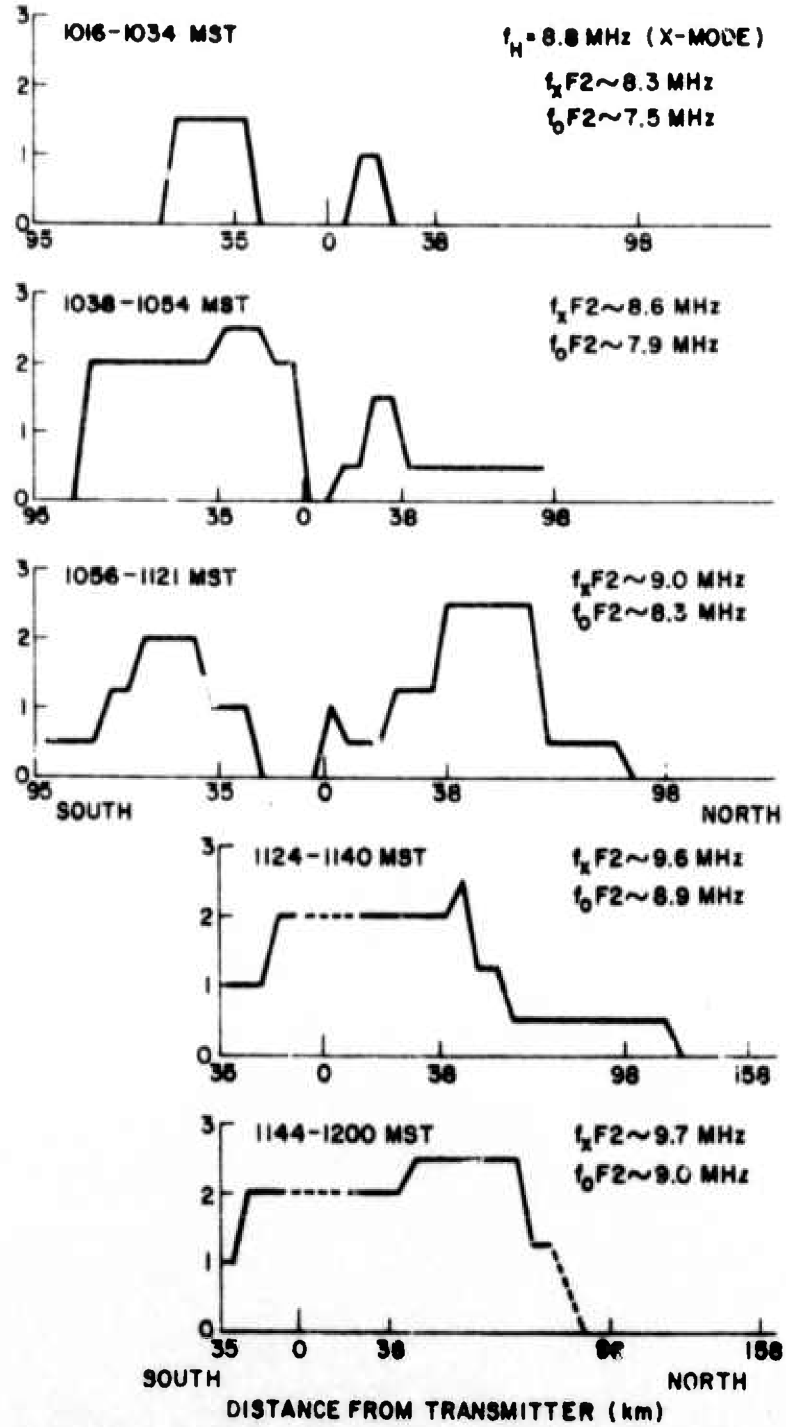


Figure 4.7 Ionogram trace width on March 31, 1971, X-mode heating (S)

4.3 Satellite Experiment (U)

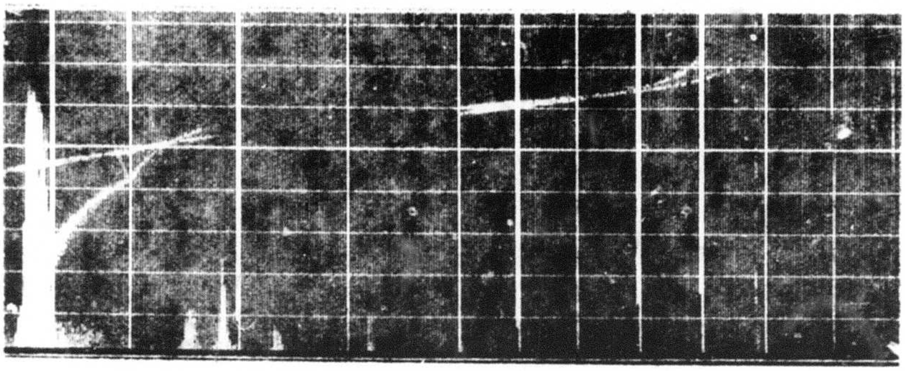
(S) Since ASF, in common with naturally occurring spread F, seems to extend in a field-aligned manner throughout the F layer, it seems reasonable to suppose that it is visible in the topside as well as the bottomside of the layer. Four topside sounders are presently in orbit; Alouette I and II and ISIS (International Satellite for Ionosphere Studies) I and II (see Table 4.2). These contain sounders which sweep continuously in frequencies up to 20 MHz, recording the "virtual depth" of the return from the topside of the F layer.

(S) At 1408 MST on April 10, 1972, the satellite ISIS II passed 23 km to the east of Platteville at an altitude of 1423 km, in a wouthward direction; its maximum elevation at Platteville was 89 deg. Ionograms were taken at 22.5 sec intervals, and telemetered to the Ottawa readout station.

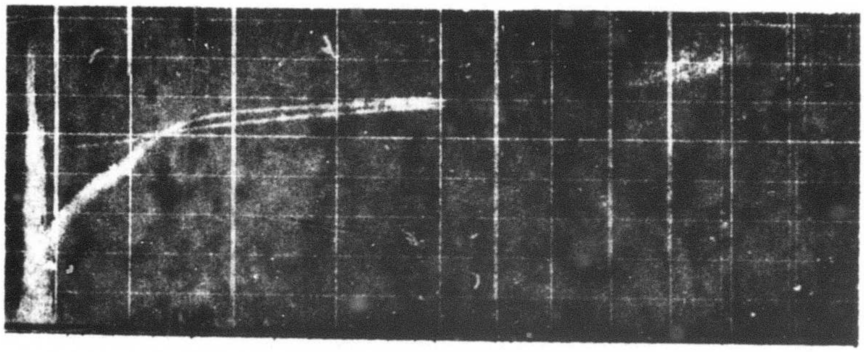
(S) Figure 4.8 shows a sequence of five such ionograms taken at equal intervals around the time of transit over the heater transmitter. Virtual depth increases upwards (height markers are at 100 km intervals) and frequency increases to the right, to emphasize the resemblance to conventional ionograms. The value of foF2 increases from 9.4 to 10.4 MHz from beginning to end of the sequence; frequency markers are at 1 MHz intervals in that vicinity. Figure 4.8 (e), with the satellite substantially south of Platteville, shows very thin and well-defined O and X traces; as does Figure 4.8 (a), for which it was to the north. Figures 4.8 (b) and (c) on the other hand, show very substantial spread of the O and X traces surrounding the time of transit over Platteville. The missing portions of these traces (including the O and X penetration on Figure 4.8 (d)) are due to satellite roll placing the null of the satellite transmitting antenna towards the ground. The total elapsed distance for the five traces is about 600 km.

Table 4.2

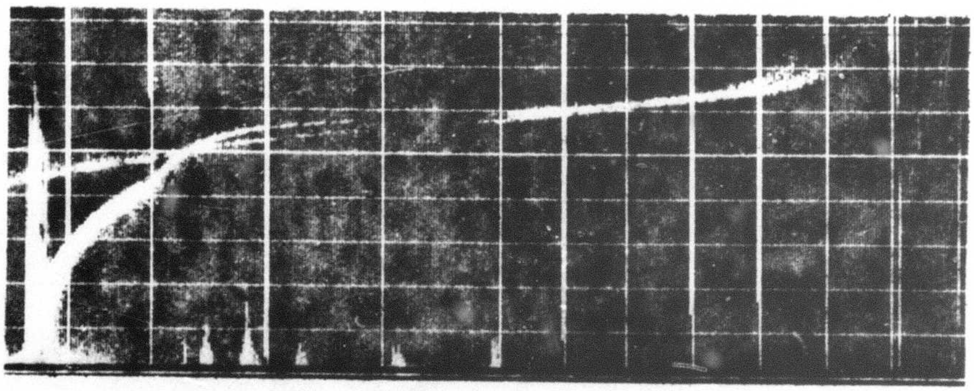
Satellite	Apogee (km)	Perigee (km)	Inclination (deg)	Lowest Sounder Frequency (MHz)
Alouette I	1000	1000	80	0.5
Alouette II	3000	500	79	0.1
ISIS I	3500	500	90	0.1
ISIS II	1420	1420	90	0.1



1407:01 MST

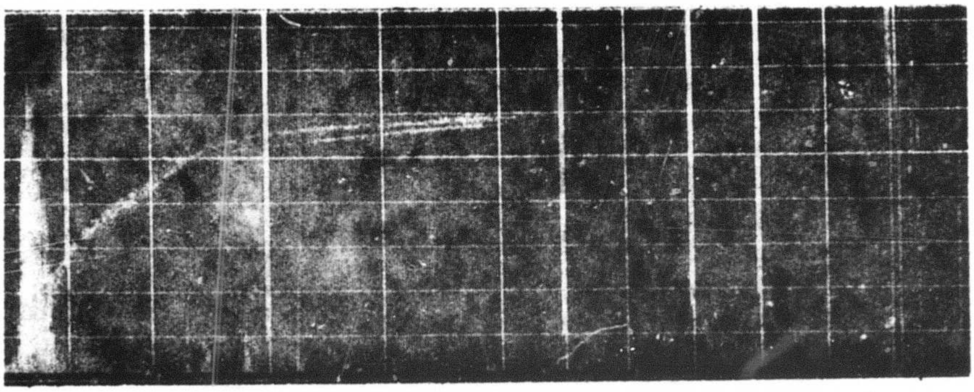


1407:23 MST

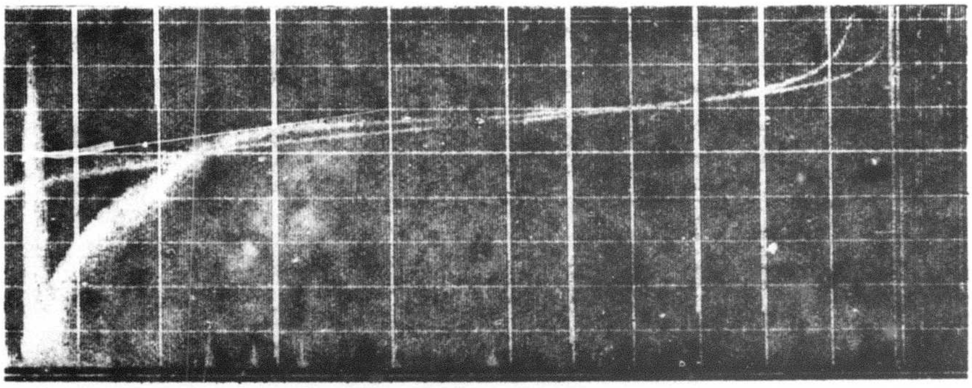


1407:46 MST

Figure 4.8 Topside sounder ionogram sequence (S)



1408:08 MST



1408:31 MST

Figure 4.8 Topside sounder ionogram sequence (S) (concluded)

(S) Because the spread of the O and X traces is comparable with that normally observed on a ground-based ionogram, it is concluded that ASF is at least as strong on the topside of the F layer as on the bottomside, and is not confined to heights in the neighborhood of the reflection height of the heater. It is further concluded that the topside sounder can be used to map the horizontal extent of the disturbed region; though a fixed-frequency mode will give improved spatial resolution.

5. SYMMETRICAL BISTATIC GEOMETRY TO MAXIMIZE TOTAL CROSS SECTION (U)

5.1 Introduction (U)

(S) Many monostatic studies have been made of field-aligned scatter from small-scale irregularities due to ionospheric heating, with the radar located in the same magnetic meridian of the heater, but considerably to the south. For this geometry, the surface of orthogonality is dome-shaped, as calculated by Thome (Proceedings of Prairie Smoke I RF Measurements Data Workshop, p. 65), with the peak of the dome considerably to the north of Platteville. Consequently, the orthogonality surface (or h_Q surface) slopes downwards to the south over Platteville. As shown by Bowhill (Proceedings of Prairie Smoke RF Scatter Model Workshop, pp. 105-110) this results in a substantial reduction in the total scattering cross section, in that the relatively thin (about 25 km thick) region of irregularities is intercepted by the h_Q surface over a relatively small fraction of the total disturbed area. Therefore, any configuration which flattens the h_Q surface enhances the scattering cross section. To put it another way, the requirement is to move the Thome dome in the h_Q surface so that it is centered over Platteville at the altitude of the disturbed region.

(S) In Section 5.2, it is shown that this can be accomplished by a proper choice of bistatic angle; and that too large a bistatic angle will produce an h_Q surface which slopes downwards to the north rather than to the south.

5.2 Geometry of the Problem (U)

(S) The magnetic field model adopted is a simple dipole, to permit an analytical solution to the problem. The Cartesian coordinate system has the dipole as the x axis, with the magnetic equator in the (y,z) plane; the (x,z) plane passes through the center P of the disturbed region and defines the prime magnetic meridian. The points Q, Q' on the earth's surface which form the

bistatic pair have magnetic latitude θ_2 and magnetic longitudes of ϕ and $-\phi$.

(S) Let θ_1 = magnetic latitude of P

δ = magnetic dip at P

R = earth radius

h = height of P above earth's surface

$\underline{B}$ = earth's magnetic flux density at P.

Then

$$B_x = B\cos(\delta+\theta_1)$$

$$B_y = 0$$

$$B_z = -B\sin(\delta+\theta_1)$$

Coordinates of P are $[(R+h)\sin\theta_1,\ 0,\ (R+h)\cos\theta_1]$

Coordinates of Q are $[R\sin\theta_2,\ R\cos\theta_2\sin\phi,\ R\cos\theta_2\cos\phi]$

and the components of the vector $\underline{PQ}$ are:

$$[PQ]_x = R\sin\theta_2 - (R+h)\sin\theta,$$

$$[PQ]_z = R\cos\theta_2\cos\phi - (R+h)\cos\theta.$$

The orthogonality condition is $\underline{PQ}\cdot\underline{B} = 0$, or

$$B_x[PQ]_x + B_z[PQ]_z = 0, \text{ or}$$

$$R\sin\theta_2\cos(\delta+\theta_1) - R\cos\theta_2\cos\phi\sin(\delta+\theta_1) + (R+h)\sin\delta = 0. \tag{1}$$

Now let us determine the condition that the h_0 surface is flat; namely, that $\partial h/\partial\theta_1 = 0$. Let the rate of change of dip with latitude be $u \equiv \partial\delta/\partial\theta_1$. It follows that

$$-R(1+u)\sin\theta_2\sin(\delta+\theta_1) - R(1+u)\cos\theta_2\cos\phi\cos(\delta+\theta_1) + u(R+h)\cos\delta = 0. \tag{2}$$

Equations (1) and (2) can be solved for θ_2 and ϕ as follows:

$$\sin\theta_2 = \frac{R+h}{R(1+u)}[u\sin\theta_1 - \sin\delta\cos(\delta+\theta_1)] \tag{3}$$

$$\cos\phi\cos\theta_2 = \frac{R+h}{R(1+u)}[u\cos\theta_1 + \sin\delta\sin(\delta+\theta_1)]\ . \tag{4}$$

From Equations (3) and (4), magnetic latitudes, θ_2, and longitudes ϕ, can be calculated for points Q that satisfy the orthogonality <u>and</u> h_Q-surface flatness conditions simultaneously.

(S) For a dipole field,

$$\theta_1 = \arc\tan (1/2 \tan \delta)$$

$$u = (1+3 \cos^2 \delta)/2.$$

As an example, values of θ_2 and ϕ are given in Table 5.1 for magnetic dips δ of 68.2° and 68.5°, the range typically assumed for Platteville. For comparison, the magnetic latitude of White Sands is about 41.1°.

Table 5.1

Optimum bistatic coordinates (U)

h(km)	δ = 68.2°		δ = 68.5°	
	θ_2	ϕ	θ_2	ϕ
200	37.60	17.67	38.19	17.34
220	37.74	16.77	38.33	16.41
240	37.87	15.82	38.47	15.42
260	38.01	14.81	38.60	14.36
280	38.14	13.71	38.74	13.20
300	38.28	12.51	38.88	11.93
320	38.41	11.19	39.02	10.50
340	38.55	9.67	39.16	8.84

6. CONCLUSIONS (U)

6.1 Conclusions from Prairie Smoke III (U)

(S) Wide-spaced-reciever studies of orbital-satellite scintillations during Prairie Smoke III have demonstrated two types of ASF distribution around the heater transmitter. The first, associated with very substantial distortion of the gross electron density contours, is doughnut-shaped and displaced from the meridian; the other, associated with a smoother electron density distribution, accords with the more classical picture of a Gaussian distribution of ASF, centered on the heater location.

(S) Transmission experiments at 30 and 50 MHz using pulsed beacon satellites show rapid and complex fading of a relatively wide region surrounding the heater transmitter, with much deeper scintillation than found at higher frequencies.

(S) Fine structure (less than 10 m) has been unambiguously detected for the first time using the satellite transmission experiment.

6.2 Conclusions from Prairie Smoke IV (U)

(S) Structure variations of the scintillation index of a geostationary satellite signal were observed, which appear to be correlated with changes in transmitter power and frequency. Detailed conclusions await completion of the analysis.

6.3 Conclusions from Mobile Diagnostics (U)

(S) From the aircraft and ionosonde diagnostics described in Section 4, it appears that:

1) A properly instrumented aircraft-borne ionosonde can map the horizontal extent and intensity of ASF.

2) The southern boundary of ASF is about 90 km south of Platteville, and the northern boundary is more than 100 km north.

3) The southern boundary is somewhat more abrupt than the northern.

4) When the heater frequency is above foF2, the disturbed region is dough-nut shaped, with the hole centered approximately over Platteville.

5) Topside sounder satellites are capable of detecting ASF, though hampered by the relative infrequency of their sweep in relation to the satellite velocity.

6) ASF was found to be at least equally intense when seen from the topside as when seen from the bottomside of the F layer, supporting the concept that the electron density fluctuations in ASF are proportional to the electron density throughout the F layer.

6.4 Conclusions Concerning Optimum Bistatic Geometry (U)

(S) It has been shown that there is a particular bistatic geometry which will produce a flat h_Q surface at a prescribed height in the F region over a heating transmitter, thereby giving a maximum total scattering cross section. As an example, the path Brownsville, Tex. - Platteville, Colo. - San Diego, Cal. is close to optimum for this magnetic field model. The following suggestions follow from this analysis:

1) Yield measurements for bistatic geometry must be corrected for the effects of a sloping h_Q surface;

2) Systems planners should note the range constraints indicated for bistatic operation;

3) Calculations should be repeated for other than the dipole model;

4) The tilt of the h_Q surface is not a significant factor for a heater located on the magnetic equator.

6.5 Overall Summary (U)

(S) Characteristics of the scintillations observed to date are summarized in Table 6.1. Table 6.2 summarizes aspects of the phenomenon which are not yet

Table 6.1

Highlights of transmission experiment results (U)

FIELD-ALIGNED STRUCTURE GIVES STRONG VHF AND UHF SCINTILLATIONS UP TO 400 MHz

SCINTILLATIONS MAXIMIZE AROUND UPFIELD DIRECTION

FADING DEPTH VARIES INVERSELY WITH FREQUENCY

TRANSVERSE SCALE $\sim$ 100 m, CONVECTS WITH PLASMA MOTION (20-50 m sec^{-1})

STRUCTURE EXTENDS 200 TO 450 KM ALTITUDE

EXTENDS HORIZONTALLY 50 TO 100 KM RADIUS

REGION SOMETIMES DOUGHNUT-SHAPED

MICROSTRUCTURE $\sim$ 10 m OR LESS HAS BEEN SEEN

Table 6.2

Future studies needed of ASF using the transmission experiment (S)

HEIGHT DISTRIBUTION
ASPECT DEPENDENCE (CLOSE TO UPFIELD)
DETAILED CORRELATION FUNCTIONS IN TIME AND SPACE
YIELD STUDIES
HORIZONTAL MORPHOLOGY
OTHER LATITUDES (EQUATORIAL, AURORAL)

understood; some of these are currently under study and will be described in future reports.

APPENDIX

IVORY CORAL APPLICATIONS AND DIAGNOSTICS (U)

ABSTRACT (U)

(S) Studies are described on four experiments that may play a role in IVORY CORAL studies of the heated ionosphere. These are a study of a mobile heater facility; a remote experiment to study conjugate-point effects; a transmission experiment using orbital and geostationary satellites; and a rocket aperture-synthesis experiment.

TABLE OF CONTENTS (U)

1. MOBILE FACILITY RECOMMENDATIONS (U)

(S) This section describes the results of some studies carried out on the utility and criteria for the design of a mobile heater facility.

1.1 Introduction (U)

(S) At the IVORY CORAL Data Workshop in Albuquerque, a Working Group was appointed to consider the desirability of procurement by ARPA of a mobile heating facility. The Working Group consisted of S. A. Bowhill (Chairman), V. J. Coyne, J. B. Frazer, and W. F. Utlaut. The Working Group had available to it the results of an unclassified study, "Transportable HF Transmitter Module", prepared by MITRE Corporation.

(S) The Working Group first considered the definition of a mobile facility, and concluded that the degree of mobility represented by the MITRE study (namely, each module packaged onto two trailers) might not be necessary, in view of the fact that deployment of the antenna would probably be the limiting factor in any case. For a land-based facility, it seemed that moving the facility by truck or by air to an already available (or specially constructed) steel building might be worth considering as a much cheaper alternative.

(S) The Working Group further decided that a shipboard installation (that is to say, a module capable of being mounted on a vessel of the order of the size of an escort carrier) could not be ruled out. This is further discussed in Section 1.2.

1.2 Justification for a Mobile Facility (U)

(S) In considering the question of whether a mobile facility is needed, it is necessary to ask whether the scientific or applications aspects of the IVORY CORAL phenomenon require experimental configurations that cannot be provided by the existing installations at Platteville and Arecibo. The following seem to

be the major areas where such a facility is required:

(S) a. Research tool--The investigation of the scattering properties of artificial spread F (ASF) and wide-band attenuation (WBA) as a function of latitude, particularly at high and low latitudes, cannot be accomplished with the present installation, and a systematic program using a mobile facility is needed to gather the basic information for carrying out realistic systems studies. Of equal importance is the experimental determination of yield (namely, the amount of ASF and WBA produced for a given heating power density in the ionosphere) as a function of latitude for different conditions of ionospheric disturbance and heating frequency.

(S) b. Deployment adjacent to large fixed systems--For applications evaluation, it is important to be able to deploy a heating transmitter at a suitable range and direction from an operational system. For example, studies involving east-coast HF radar systems cannot be satisfied by the Platteville heater. As another example, deployment and testing against ABM systems requires setting up a heater in the general vicinity of KMR.

(S) c. Deployment adjacent to nonportable probing facilities--Studies of the IVORY CORAL phenomenon by large radar systems (such as PAR) or their study by rocket beacons or probes (should this be judged necessary) would require setting up a mobile heater at a suitable location.

(S) d. Applications tests at remote locations--There are certain applications where it will prove necessary to set up a heater at a definite fixed location. For example, if strong conjugate-point effects are seen, it would be desired to locate a mobile heater (probably ship-borne) at the geomagnetic point to the critical ionospheric location for an operational system.

(S) e. New concept testing--A mobile facility, particularly if constructed on the modular concept, would prove very useful for testing new aspects of ASF or

WBA; for example, the use of thinned antenna arrays to produce a high energy density for the same input power.

1.3 Features Required in a Mobile Facility (U)

(S) The question of the characteristics required for a mobile facility was discussed at some length. It was agreed that a power in the range 150-500 kw would be the most appropriate, depending on the type of antenna used.

(S) In both the ITS and MITRE designs, the antenna cost is a small fraction of the cost of the transmitter, while maximizing the energy density in the ionosphere for a fixed dollar expenditure would require approximately equal investments in the antenna and the transmitter. Therefore, much larger antennas should be considered. Steerability is not required for the mobile facility, and open-wire line should be considered as an alternative to the very expensive coaxial cable of the MITRE study; or, alternatively, cheap coaxial line of the kind used by ITS might be employed.

(S) It was felt that the concept of an automatic-tuning transmitter with modulation capability should be retained from the MITRE study.

1.4 Recommendations (U)

(S) From all of the above considerations, the Working Group made the following recommendations:

a. ARPA should procure a mobile heating transmitter with the features described in Section 1.3, but less elaborately mobile than the MITRE facility and having a substantially reduced cost.

b. In conjunction with this procurement, ARPA should arrange for a study of antenna concepts leading to a revised antenna design for the mobile facility.

c. A study should be made of the most appropriate auxiliary instrumentation (eg., radio, optical, magnetometric) to accompany the mobile facility.

d. The facility design should be compatible with ship-borne operation.

2. REMOTE EXPERIMENT (U)

2.1 Introduction (U)

(S) An experiment to investigate southern-latitude conjugate-point effects generated by ionospheric heating was suggested by Bowhill, et al. (1971a) in Section 3 of that report (dated January 1971). Noting that the ground-based ionosonde gave what appeared to be the most sensitive indication of ASF, it was decided to explore whether an airborne ionosonde could be used at the conjugate point. To this end, an experiment was carried out over Boulder in January 1971, to determine whether an airborne instrument would prove satisfactory. The results of this experiment were described in a later report (Bowhill 1971b, Section 3). It appeared that the ionosonde used would prove satisfactory; however, that aircraft is heavily committed to other programs, so alternative arrangements were sought.

2.2 Planning for Remote Experiment (U)

(S) During the IVORY CORAL 1971 Planning Session, discussions were held concerning implementation of the remote experiment. Contributions were made by D. M. Kerr and J. H. Wolcott (LASL); A. M. Peterson (SRI); J. R. Davis (NRL); and V. J. Coyne (RADC).

(S) It was noted that the AFCRL aircraft-borne ionosonde system was found to be able to detect ASF even in the presence of rather severe radio interference. In regard to this interference, two points can be made. Firstly, the interference at the conjugate point is certain to be much less, as it is far from land in all directions; and secondly, the use of a "chirp" ionosonde (rather than the conventional ionosonde in the AFCRL aircraft) should give improved protection against such interference.

(S) Accordingly, it was decided to recommend aircraft measurements at the magnetic

conjugate point to Boulder with an aircraft-borne instrument consisting of a vertical-incidence sounder (preferably of the chirp type), a magnetometer to look for micropulsation activity (Bowhill, 1971a) and perhaps some optical observations (eg., 6300 A red line, and near infrared). LASL expressed an interest in the experiment, and would have no difficulty in carrying out optical experiments, or carrying a magnetometer. In addition, they have just installed in their NC-135 a vertical-incidence chirp sounder manufactured by AVCO Corporation.

(S) The latitude and longitude of the conjugate point to Boulder (40.03 N, 105.3W) are (see Bowhill, 1971a) as 54.4 S, 131.9 W. Special calculations have been run by LASL assuming a heated point at 200 km altitude, 40.01 N, 105.28 W for epoch 1971.797, using two magnetic field models. Locations found for the conjugate point are as follows:

GSFC	12-66 model:	54.66 S, 131.36 W
POGO	8-69 model:	55.08 S, 131.90 W

The GSFC 12-66 calculated point is shown as the point P on Figure 2.1. Evidently, it is far from land in any direction. Studies of the problem of reaching it from a number of available airfields have been made by J. H. Wolcott. Seven airfields were considered, and are shown on Figure 2.1: Easter Island (A), Pitcairn Island (B), Tahiti (C), Samoa (D), Fiji (E), Christchurch (F), and McMurdo (G). Serious consideration was given to Christchurch, distance 2215 NM from P, with an 8000-ft runway; and Tahiti, distance 2415 NM, with an 11,200-ft runway. Flight time for the round trip CPC is about 12 hr and for FPF is about 11 hr. Since the maximum flight time of the NC-135 is 8 hr, refueling with tankers will be necessary in either case. The plan which follows is based on always leaving the NC-135 with enough fuel to return to base, even if no further tanker rendezvous is made.

(S) The NC-135 aircraft would deploy from Kirtland AFB, New Mexico and two KC-135 tankers from the West Coast. All aircraft would operate from the same deployment

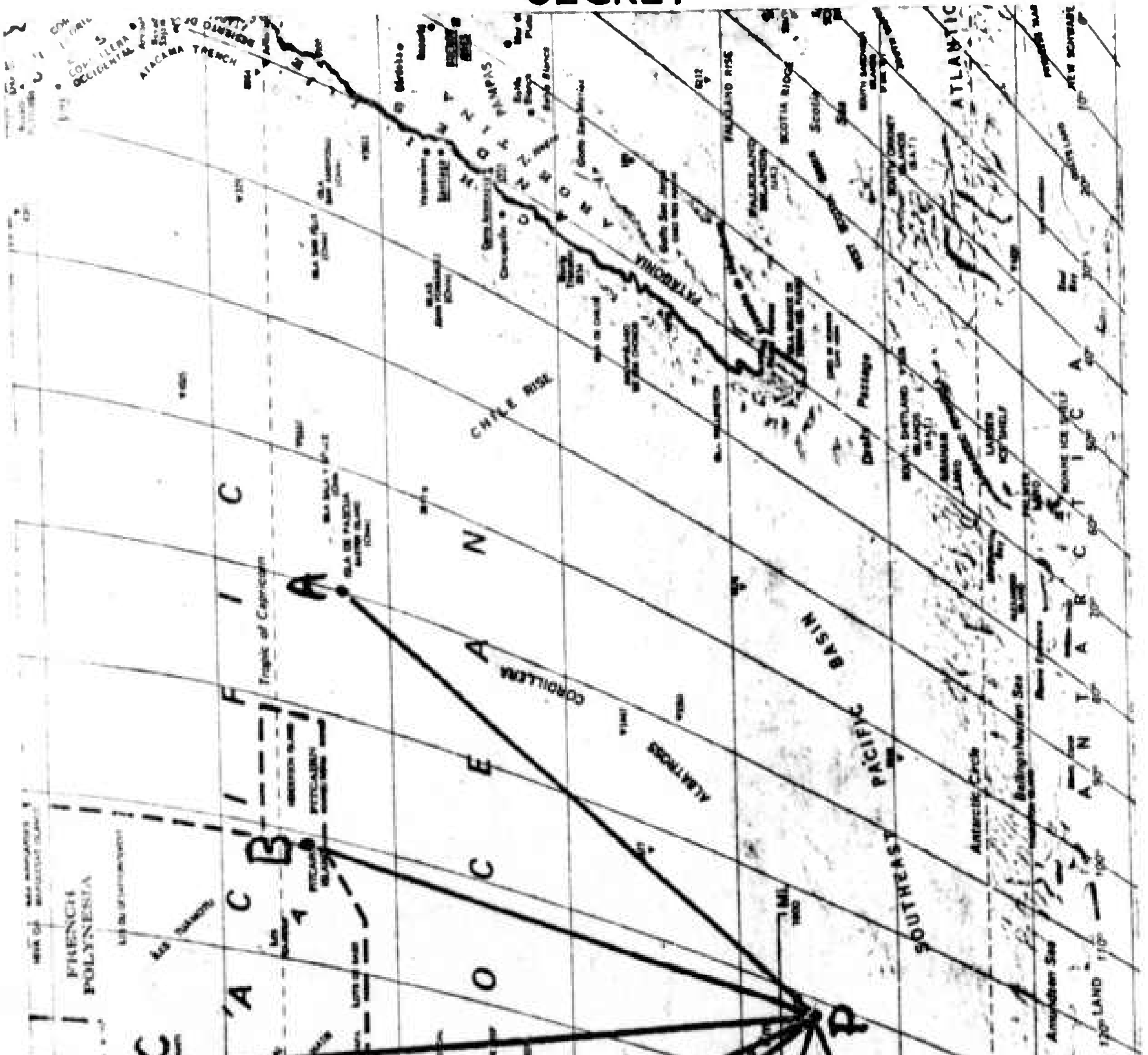

A
B
C
D
E
F
G
P
PACIFIC OCEAN
FRENCH POLYNESIA
Tropic of Capricorn
CHILE RISE
PATAGONIA
ALBATROSS CORDILLERA
SOUTHEAST PACIFIC BASIN
SOUTHWESTERN PACIFIC BASIN
Drake Passage
Antarctic Circle
Bellingshausen Sea
Amundsen Sea
International Date Line
NORTH ISLAND
SOUTH ISLAND
NEW ZEALAND
NORFOLK ISLAND TROUGH
LORD HOWE RISE
ATLACAMA TRENCH
ATLANTIC
ANTARCTICA
BYRD LAND
Ross Sea
EMERALD BASIN
COOK ISLANDS
TONGA
Kilometers
Statute Miles

Figure 2.1

base, Christchurch, New Zealand, for three missions; aircraft could take off with a gross weight of at least 245,000 lb, and the tankers could off load a minimum of 90,000 lb of fuel between them. Enroute refueling would occur three hours after takeoff to allow a safe return in event of a malfunction. This plan would allow about three hours at the conjugate point for each mission.

2.3 Preliminary Experiment Evaluation (U)

(S) During PRAIRIE SMOKE I, in October 1971, certain aspects of this instrumentation were tested. Micropulsation instrumentation was fielded by NRL; however no conclusive results were obtained. It therefore seems doubtful whether this experiment could be fielded on an aircraft mission.

(S) The LASL aircraft ionosonde was also tested on October 12; while evaluation of the results is not complete, results were disappointing. After some changes, that ionosonde was tested on the ground at Boulder against the Barry Research chirp instrument; it was found that its performance compared quite favorably with the Barry Research instrument. However, no further airborne results are yet available.

2.4 Future Plans (U)

(S) The remoteness of the conjugate point (evident on Figure 2.1) makes aircraft experiments difficult and expensive. It seems that some information could be gathered from satellite experiment at the conjugate point; this matter should be explored. However, if the aircraft sounder experiment is proceeded with, it should be noted that the LASL aircraft will participate in conjugate eclipse measurements during the total eclipse of July 10, 1972. It will be based at Christchurch during this time, and considerable savings could be effected by combining this mission with the Remote Experiment. Therefore, it is recommended that in this case an IVORY CORAL exercise should take place in the week of 10-15 July 1972 (which begins with a new moon). It is further recommended that the

Barry Research sounder should be installed in the LASL aircraft for the Remote Experiment, to ensure redundancy of this essential measurement.

(S) Further studies should be made of the type of transmission to be provided from Boulder for this experiment; the relative usefulness of a satellite and an airborne experiment; the type of flight pattern to be followed; the mode of operation of the sounders; the criteria for success of the experiment; and the method of data analysis to be used.

3. SATELLITE EXPERIMENT (U)

(S) At the IVORY CORAL 1973 Technical Planning Session in August 1971, planning for satellite experiments for IVORY CORAL was considered by a Working Group, whose report follows in abbreviated form.

3.1 Introduction (U)

(S) It is not possible to establish a scattering model unambiguously from monostatic or bistatic radar scattering, due to the presence of multipath effects. However, by transmitting a radio signal through the disturbed region, and choosing a frequency sufficiently high so that multipath effects are substantially avoided, a rather clear picture of the irregularities can be provided. Therefore, the Working Group considered the possibility of an experiment to examine amplitude fluctuations and angle-of-arrival scintillations from orbiting and geostationary satellite signals received at VHF and UHF by spaced receivers. The Working Group took as a basis material by Bowhill *et al*. (1971a)

(U) The theory of scintillation produced by a random medium was developed initially by Hewish (1952) to assist in his interpretations of radio-star scintillations. This theory has been further developed by Bowhill (1961) and others. Provided that the structure size of the irregularities is large, compared with a wavelength, a ray-optics approach can be used to determine the properties of the wave observed at the ground. Radio signals passing through a medium having spatial fluctuations in electron density develop irregular wavefronts on emerging from the ionosphere. These produce, by focussing, amplitude fluctuations in a plane distant z from the cloud, having a fractional value of about $z(d^2/dx^2)$ (phase path), where the phase path is obtained by integrating the phase refractive index along the line of sight from the point (x,z) to the source of the radio signals.

(U) Two general configurations are useful for satellite scintillation configurations,

using orbiting and geostationary satellites. These are described separately in the following sections.

3.2 Orbiting-Satellite Configuration (U)

(S) Figure 3.1 illustrates a configuration suitable for investigation of ASF and WBA irregularities in the disturbed ionosphere. A satellite S transmits signals whose amplitude and phase are recorded at three receiving points ABC. A point P in one layer of irregularities moves with a velocity of several km sec^{-1}, much larger than any velocity thought to be present in the irregularities. Therefore, a "snapshot" of these irregularities is obtained from the orbiting satellite. Analysis of these results can determine the following properties of the irregularities:

(U) 1. If the ASF is field-aligned (from the variation of the orientation of the major axis of the projected ellipse with the orientation of the line of sight).

(U) 2. Structure size and aspect ratio of the ASF irregularities (by correlation analysis of amplitude variations at the stations ABC).

(U) 3. The distribution in altitude of the ASF and WBA irregularities (since the ratio of their apparent velocities in the plane ABC to that of the satellite is determined by the height at which they are located).

(U) 4. The horizontal extent of the irregularities (from the time of onset of the scintillation for different cuts of the orbit through the heated region).

(S) 5. The nature of the small-scale structure associated with WBA (from the decorrelation of the smallest size of amplitude and scintillations).

(S) 6. The amount of scintillation in power and in angle of arrival produced by transmission through the irregularities (needed for extrapolation to the monostatic radar scattering case).

3.3 Geostationary Configuration (U)

(S) Figure 3.2 shows the configuration available for a geostationary satellite. Since all such satellites are located in the equatorial plane, their lines of sight are all somewhat to the south, so the three-station network must be offset

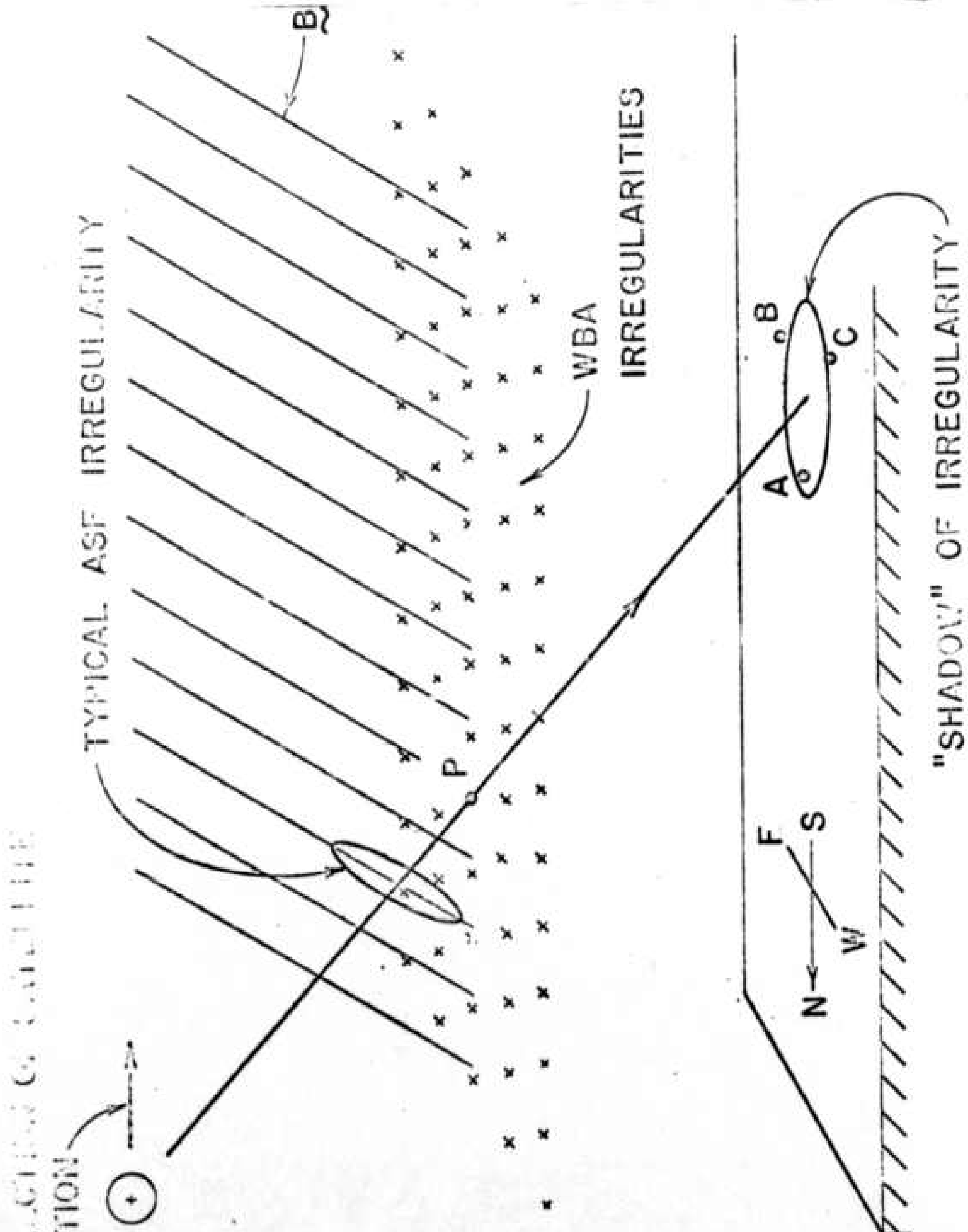

MOTION
S
TYPICAL ASF IRREGULARITY
B
WBA
IRREGULARITIES
P
A
B
C
"SHADOW" OF IRREGULARITY
F
S
N
W

Figure 3.1

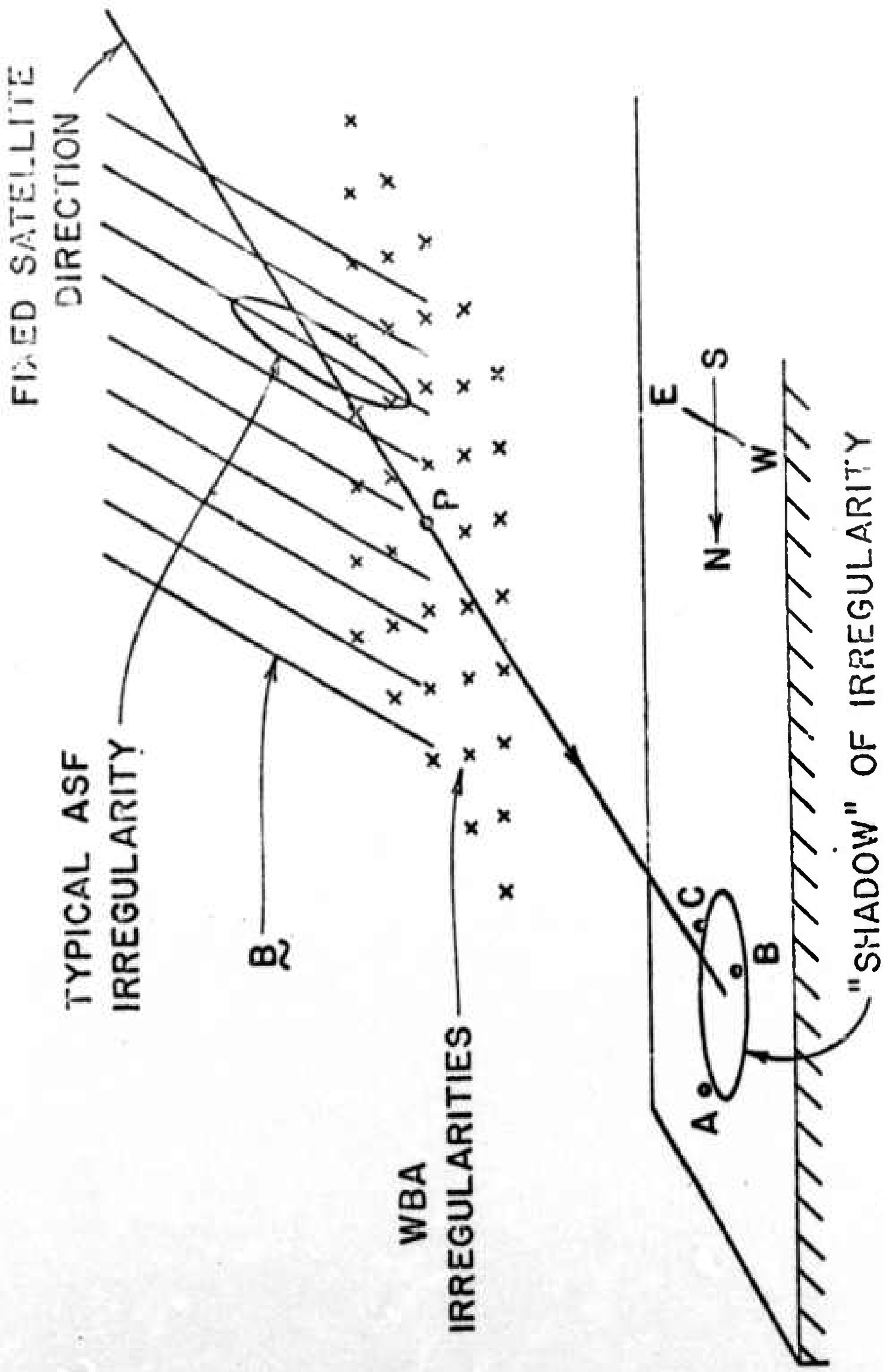

FIXED SATELLITE DIRECTION
TYPICAL ASF IRREGULARITY
B
WBA IRREGULARITIES
P
E
S
N
W
A
B
C
"SHADOW" OF IRREGULARITY

Figure 3.2

from the center of the disturbed region in order to observe scintillations. Here, the line of sight is virtually stationary, so the observations obtained are complementary to the orbiting satellite observations in that time variabilities are dominant. Analysis of data from this experiment can give:

(U) 1. The drift velocity of the irregularities if present (from correlation analysis).

(U) 2. The time behavior of the irregularities relative to the switch-on and switch-off of heating.

(S) 3. Scatter of energy at large angles to the line of sight (i.e., when the ray path does not intersect the heated volume).

(S) 4. Scatter of transmitted energy at frequencies displaced from the transmitted frequency.

3.4 Available Satellites (U)

(U) The following satellites, currently transmitting, would be suitable candidates for this type of study:

Orbiting satellites

	ISIS-A	Transit
Period	128 min	90 min
Inclination	88 deg	90 deg
Altitude	580-3520 km	1000 km
Frequencies	138 MHz	150 and 400 MHz

Geostationary satellites

	ATS-I	ATS-V
Longitude	149°W	105°W
Elevation angle	27 deg	44 deg
Frequency	137 MHz	136 MHz
Ground station latitude	43.4°N	42.9°N
Ground station longitude	96.2°W	104.3°W

3.5 Other Satellite Experiments (U)

(U) Consideration should be given to a number of other experiments that could be carried out without the need for specifically instrumented satellites:

(U) 1. Using Langmuir probes on existing satellites, to search for field-aligned enhancements in electron temperature above the heated region.

(S) 2. Using electron or ion current measurements to study the morphology of the ASF and WBA irregularities from satellites passing through the distrubed region.

(U) 3. Using retarding-potential analyzers in the 1-1000 eV range, to search for non-Boltzmann electrons that have migrated from a region of parametric instability (perhaps the WBA region) to higher altitudes.

(U) 4. Using satellite-borne filter photometers, to search for enhanced airglow lines at night in the disturbed region.

(U) 5. Using topside-sounder satellites, to study instabilities, produced by RF fields surrounding the satellite, which may be analogous to the instabilities that produce WBA.

(S) 6. Using satellites which can be seen from White Sands Proving Ground through the disturbed region, to look at scintillations in amplitude and in angle of arrival at UHF for comparison with the satellite transmission data described in Section 3.2.

4. ROCKET EXPERIMENT (U)

4.1 Introduction (U)

(S) A planned rocket experiment was described by Bowhill (1971o, Section 4) involving use of the Nike-Apache rocket to synthesize a large antenna aperture in receiving HF signals propagated obliquely but reflected from the ionosphere. This section describes preliminary results from the experiment.

4.2 Rocket Experiment Results (U)

(S) Nike-Apache 14.475 was launched from Wallops Island, Virginia, at 09:19 UT on Friday 20 August 1971.

(S) In addition to other instruments, the rocket carried a receiver to measure the relative amplitude and phase of signals; A, originating from Wallops Island, and B, originating from a transmitter of the Stanford Research Institute at Lost Hills, California. A synthesizer, provided by SRI, was used to drive the transmitter at Wallops Island (radiating the ordinary mode), and to provide a phase reference.

(S) On the night of 18 August 1971, best signals from Lost Hills were received on the ground at Wallops Island when the beam was directed at an azimuth of 78°. A natural fading period of from two to four seconds was observed. The power of the SRI transmitter was about 10kW.

(S) On the morning of the rocket flight, the power of the Wallops Island transmitter was adjusted as the rocket was in flight in an attempt to maintain a 30% modulation of signal A by signal B at a beat frequency of 500 Hz. The parameters of the system which accomplished this objective were as follows:

Frequency of Wallops Island transmitter (driven by SRI synthesizer)	7 922 000 Hz
Frequency of SRI transmitter at Lost Hills	7 921 500
Beat frequency (free space, w/o Doppler correction)	500 Hz

Center frequency of rocket receiver		7 922 500 Hz
Bandwidth of rocket receiver	(6 dB)	8 570 Hz
		(as of 27 April 1971)
	(3 dB)	5 430 Hz
		(as of 27 April 1971)

(S) Figures 4.1 through 4.6 are reproductions of the telemetered output signal from the rocket receiver, corresponding to altitudes of 80, 100, 120, 140, 160, and 180 km, respectively. The upper trace is the signal from a propagation experiment at 2225 kHz and should be ignored for the purposes of the present discussion.

(S) Following the lower trace, of interest here, note that the 500 Hz beat frequency is present in all six figures.

(S) On the average, the modulation ratio is held to about 30% as intended.

(S) In addition to the 30% modulation at the 500 Hz beat frequency, there is ample evidence of more complicated interference patterns in all six figures. Quasiperiodic fading of longer periods, which sometimes reduce the modulation ratio to zero, is evident in all six figures. Some of this can be attributed to the manual adjustment of the desired 30% modulation for which there is an independent record of the Wallops Island transmitter power as a function of time.

4.3 Future Plans (U)

(S) The potential usefulness of this technique for IVORY CORAL and other applications will be explored.

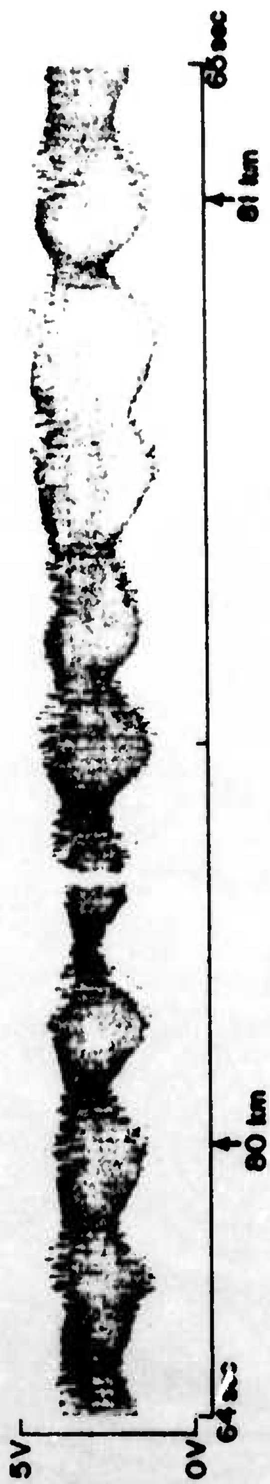


Figure 4.1

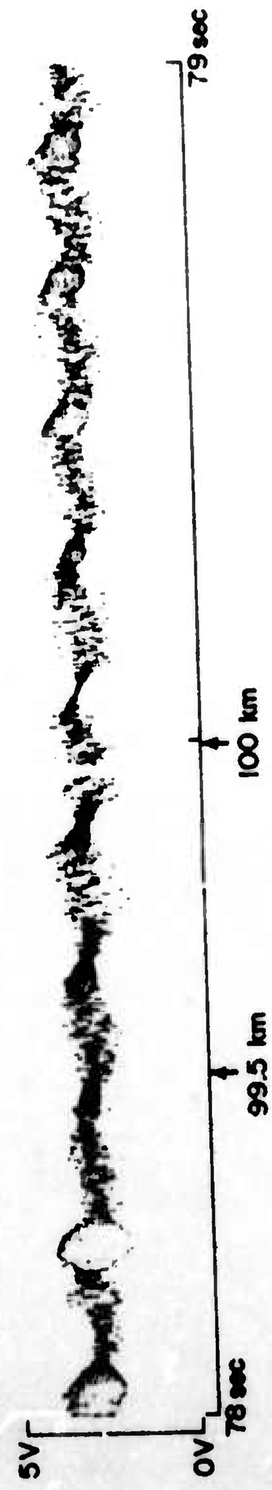


Figure 4.2

Figure 4.3

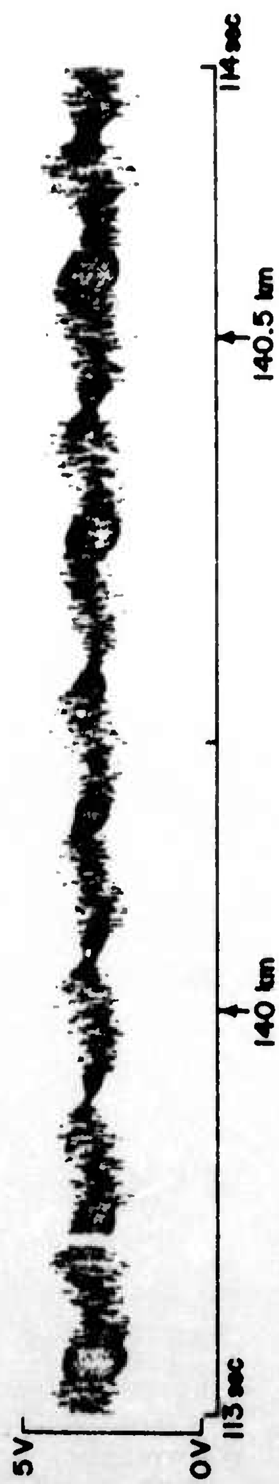


Figure 4.4

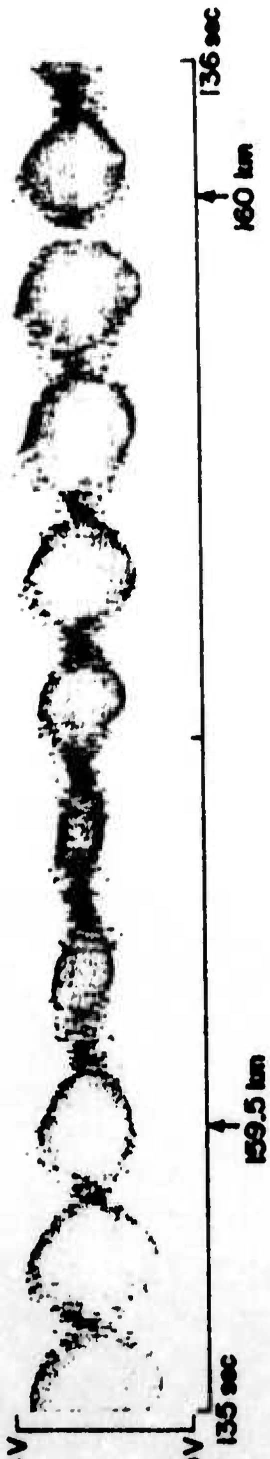


Figure 4.5

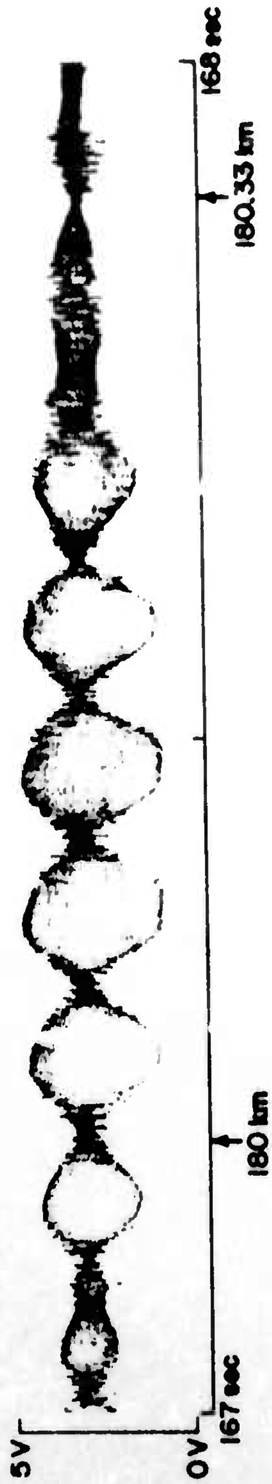


Figure 4.6

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Hewish, A., The diffraction of galactic radio waves as a method of investigating the irregular structure of the ionosphere, Proc. Royal Soc. A214, 494, 1952. UNCLASSIFIED.

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13. ABSTRACT

(S) This report describes satellite transmission experiments carried out in Prairie Smoke III and IV to study the structure sizes and time dependence of scintillations ~~to study the structure sizes and time dependence of scintillations~~ produced by artificial spread F (ASF) irregularities at frequencies of 30, 50, 150, and 400 MHz. Fine structure down to less than 10 m was identified in the scintillating signals. Aircraft and topside sounder diagnostics are described for earlier experiments, which show that the disturbed region extends more than 200 km in a north-south direction, with a relatively sharp southern boundary. This report also presents a criterion for optimization of the bistatic cross section for on-frequency scatter (OFS) at VHF and UHF by a suitable choice of geometry.

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